North Carolina State Record

NORTH CAROLINA STATE UNIVERSITY 1972-74 GRADUATE CATALOG

December, 1971

NORTH CAROLINA STATE RECORD

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Maxine F. Shane, University Catalog Editor; Joseph S. Hancock, Assistant Director, Publications; Hardy D. Berry, Director, Information Services.

North Carolina State University

Raleigh, North Carolina

Graduate Catalog
1972-74

North Carolina State University

North Carolina State University was established in March, 1887, by the General Assembly of North Carolina as the State's Land grant institution.

The Land-grant designation originated with the federal Morrill Act of 1862, signed by President Lincoln, granting federal lands to each state for endowment purposes if the state would establish a publicly-supported college or university offering education in the agricultural sciences and mechanic arts and including classical studies. The Morrill Act founded a national system of major public institutions, now well known state universities of the nation.

In 1889, the new institution in North Carolina opened as North Carolina College of Agriculture and Mechanic Arts. In recognition of its development, the North Carolina General Assembly in 1965 renamed the institution North Carolina State University at Raleigh.

In 1931, the General Assembly merged three institutions in the State, North Carolina State College of Agriculture and Engineering, The University of North Carolina at Chapel Hill and The University of North Carolina at Greensboro into The University of North Carolina.

In the 1960's, The University of North Carolina was expanded and three additional institutions were incorporated into the University system—The Universities of North Carolina at Asheville, Charlotte and Wilmington.

In 1971 all of North Carolina's 4 year public institutions of higher education (15 universities and the School of Arts) were incorporated by law as constituent institutions into a statewide system which continues as The University of North Carolina.

The University of North Carolina system has a 32 member Board of Governors with a President as the chief administrative officer.

Each constituent institution is administered by a Chancellor with the advice of a 13-member Board of Trustees.

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THE CALENDAR*

FALL SEMESTER 1971

August 18-22	Wed.-Sun.	Opening days (counseling, advising, late orientation, etc.).
August 23	Mon.	General faculty meeting.
August 23-24	Mon.-Tues.	All students complete registration.
August 25	Wed.	Change day (late registration, drop/add).
August 26	Thurs.	First day of classes.
September 2	Thurs.	Last day to add a course. *Last day for filing application for admission to candidacy for students expecting to complete requirements for the master's degree in December, 1971.*
September 6	Mon.	Holiday.
September 9	Thurs.	Last day to withdraw (or drop a course) with refund; last day to drop a course without a grade.
October 15	Fri.	Mid-term reports due.
November 1	Mon.	*Meeting of the Graduate Executive Council of the University of North Carolina.*
November 12	Fri.	*Deadline for submission of theses in final form to the Graduate School by candidates for the master's and doctoral degrees in December, 1971. Last day for taking final oral examinations by candidates for master's degrees not requiring theses.*
November 23	Tues.	Thanksgiving holidays begin at 10:00 p.m.
November 29	Mon.	Classes resume at 8:00 a.m.
December 10	Fri.	Last day of classes.
December 11-12	Sat.-Sun.	Reading days.
December 13-20	Mon.-Mon.	Final examinations.

SPRING SEMESTER 1972

January 10	Mon.	Opening day (counseling, advising, new student orientation, etc.).
January 10	Mon.	All students complete registration.
January 11	Tues.	Change day. (Late registration, drop/add).
January 12	Wed.	First day of classes.
January 19	Wed.	Last day to add a course. *Last day for filing applications for admission to candidacy for students expecting to complete requirements for the master's degree in May and July, 1972.*

NOTE: Chairmen of doctoral advisory committees are reminded to schedule preliminary examinations for their students at least one semester before the anticipated date for scheduling the final oral examination.

*The calendar is tentative, subject to approval of the Board of Trustees.

January 26	Wed.	Last day to withdraw (or drop a course) with refund; last day to drop a course without a grade.
March 3	Fri.	Mid term reports due. Spring vacation begins at 10:00 p.m.
March 13	Mon.	Classes resume at 8:00 a.m.
March 31	Fri.	*Deadline for submission of theses in final form to the Graduate School by candidates for the master's and doctoral degrees in May, 1972. Last day for taking final oral examination by candidates for master's degrees not requiring theses.*
April 3	Mon.	Holiday.
April 28	Fri.	Last day of classes.
April 29-30	Sat.-Sun.	Reading days.
May 1-May 10	Mon. Sat. Mon.-Wed.	Final examinations.
May 13	Sat.	Commencement.

SUMMER SESSIONS 1972

First Session

May 29-30	Mon.-Tues.	Opening days (counseling, advising, etc.).
May 31	Wed.	Registration day and payment of fees. Late registration fee for those who register after 12:00 noon, May 31.
June 1	Thurs.	First day of classes.
June 6	Tues.	Last day to register; last day to withdraw (or drop a course) with refund; last day to drop a course without a grade.
June 8	Thurs.	*Deadline for submission of theses in final form to Graduate School by candidates for master's and doctoral degrees in July, 1972. Last day for taking final oral examinations by candidates for master's degrees not requiring theses. Last day for filing application for admission to candidacy for students expecting to complete requirements for the master's degree in August, 1972.*
July 4	Tues.	Holiday.
July 6	Thur.	Last day of classes.
July 7	Fri.	Final examinations.

Second Session

July 11-12	Tues. Wed.	Opening days (counseling, advising, etc.).
July 13	Thurs.	Registration day. Registration and payment of fees. Late registration fee for those who register after 12:00 noon July 13.

NOTE: Chairmen of doctoral advisory committees are reminded to schedule preliminary examinations for their students at least one semester before the anticipated date for scheduling the final oral examination.

July 14	Fri.	First day of classes.
July 19	Wed.	Last day to register; last day to withdraw (or drop a course) with refund; last day to drop a course without a grade.
July 20	Thur.	*Deadline for submission of theses in final form to the Graduate School by candidates for the master's and doctoral degrees in August, 1972. Last day for taking final oral examinations by candidates for the master's degree not requiring theses.*
August 17	Thur.	Last day of classes.
August 18	Fri.	Final examinations.

FALL SEMESTER 1972

August 21-25	Mon.-Fri.	Opening days (counseling, advising, late orientation, etc.).
August 28	Mon.	General faculty meeting. All students complete registration.
August 29	Tues.	Change day (late registration, drop/add).
August 30	Wed.	First day of classes.
September 4	Mon.	Holiday.
September 6	Wed.	Last day to add a course. *Last day for filing application for admission to candidacy for students expecting to complete requirements for the master's degree in December, 1972.*
September 13	Wed.	Last day to withdraw (or drop a course) with refund; last day to drop a course without a grade.
October 20	Fri.	Mid-term reports due.
November 10	Fri.	*Deadline for submission of theses in final form to Graduate School by candidates for the master's and doctoral degrees in December, 1972. Last day for taking final oral examination by candidates for master's degrees not requiring theses.*
November 22	Wed.	Thanksgiving holidays begin at 1:00 p.m.
November 27	Mon.	Classes resume at 8:00 a.m.
December 8	Fri.	Last day of classes.
December 9-10	Sat. Sun.	Reading days.
December 11-20	Mon.-Sat. Mon.-Wed.	Final examinations.

SPRING SEMESTER 1973

January 8	Mon.	Opening day (counseling, advising, new student orientation, etc.). All students complete registration.

NOTE: Chairmen of doctoral advisory committees are reminded to schedule preliminary examinations for their students at least one semester before the anticipated date for scheduling the final oral examination.

January 9	Tues.	Change day (late registration, drop/add).
January 10	Wed.	First day of classes.
January 17	Wed.	Last day to add a course. *Last day for filing application for admission to candidacy for students expecting to complete requirements for the master's degree in May and July, 1973.*
January 24	Wed.	Last day to withdraw (or drop a course) with refund. Last day to drop a course without a grade.
March 2	Fri.	Mid-term reports due. Spring vacation begins at 10:00 p.m.
March 12	Mon.	Classes resume at 8:00 a.m.
March 30	Fri.	*Deadline for submission of theses in final form to the Graduate School by candidates for the master's and doctoral degrees in May, 1973. Last day for taking final oral examinations by candidates for master's degrees not requiring theses.*
April 23	Mon.	Holiday.
April 27	Fri.	Last day of classes.
April 28-29	Sat.-Sun.	Reading days.
April 30-May 9	Mon.-Sat. Mon.-Wed.	Final examinations.
May 12	Sat.	Commencement.

SUMMER SESSIONS 1973

First Session

May 28 29	Mon. Tues.	Opening days (counseling, advising, etc.).
May 30	Wed.	Registration and payment of fees; late registration fee for those who register after 12:00 noon.
May 31	Thur.	First day of classes.
June 5	Tues.	Last day to register; last day to withdraw (or drop a course) with refund; last day to drop a course without a grade.
June 7	Thurs.	*Deadline for submission of theses in final form to Graduate School by candidates for the master's and doctoral degrees in July, 1973. Last day for taking final oral examinations for master's degrees not requiring theses. Last day for filing application for admission to candidacy for students expecting to complete requirements for the master's degree in August, 1973.*
July 4	Wed.	Holiday.

NOTE: Chairmen of doctoral advisory committees are reminded to schedule preliminary examinations for their students at least one semester before the anticipated date for scheduling the final oral examination.

July 5	Thur.	Last day of classes.
July 6	Fri.	Final examinations.
Second Session		
July 10 11	Tues.-Wed.	Opening days (counseling, advising, etc.).
July 12	Thur.	New student orientation; registration and payment of fees; late registration fee for those who register after 12:00 noon, July 12.
July 13	Fri.	First day of classes.
July 18	Wed.	Last day to register; last day to withdraw (or drop a course) with refund; last day to drop a course without a grade.
July 19	Thur.	*Deadline for submission of theses in final form to the Graduate School by candidates for the master's and doctoral degrees in August, 1973. Last day for taking final oral examinations by candidates for master's degrees not requiring theses.*
August 16	Thur.	Last day of classes.
August 17	Fri.	Final examinations.

FALL SEMESTER 1973

August 20 24	Mon.-Fri.	Opening days (counseling, advising, late orientation, etc.).
August 27	Mon.	General faculty meeting. All students complete registration.
August 28	Tues.	Change day. (Late registration, drop/add.) *Last day for filing application for admission to candidacy for students expecting to complete requirements for the master's degree in December, 1973.*
August 29	Wed.	First day of classes.
September 3	Mon.	Holiday.
September 5	Wed.	Last day to add a course.
September 12	Wed.	Last day to withdraw (or drop a course) with refund; last day to drop a course without a grade.
October 19	Fri.	Mid-term reports due.
November 9	Fri.	*Deadline for submission of theses in final form to the Graduate School by candidates for the master's and doctoral degrees in December, 1973. Last day for taking final oral examinations by candidates for master's degrees not requiring theses.*
November 21	Wed.	Thanksgiving holidays begin at 1:00 p.m.
November 26	Mon.	Classes resume at 8:00 a.m.

NOTE: Chairmen of doctoral advisory committees are reminded to schedule preliminary examinations for their students at least one semester before the anticipated date for scheduling the final oral examination.

December 7	Fri.	Last day of classes.
December 8-9	Sat.-Sun.	Reading days.
December 10-19	Mon.-Sat. Mon. Wed.	Final examinations.

SPRING SEMESTER 1974

January 7	Mon.	Opening day (counseling, advising, new student orientation, etc.). All students complete registration.
January 8	Tues.	Change day. (Late registration, drop/add.)
January 9	Wed.	First day of classes.
January 16	Wed.	Last day to add a course. *Last day for filing applications for admission to candidacy for students expecting to complete requirements for the master's degree in May and July, 1974.*
January 23	Wed.	Last day to withdraw (or drop a course) with refund; last day to drop a course without a grade.
March 1	Fri.	Mid-term reports due. Spring vacation begins at 10:00 p.m.
March 11	Mon.	Classes resume at 8:00 a.m.
March 29	Fri.	*Deadline for submission of theses in final form to the Graduate School by candidates for the master's and doctoral degrees in May, 1974. Last day for taking final oral examinations by candidates for master's degrees not requiring theses.*
April 15	Mon.	Holiday.
April 26	Fri.	Last day of classes.
April 27 28	Sat.-Sun.	Reading days.
April 29-May 8	Mon.-Sat. Mon.-Wed.	Final examinations.
May 11	Sat.	Commencement.

SUMMER SESSIONS 1974

First Session

May 27	Mon.	Opening day (counseling, advising, etc.).
May 28	Tues.	Registration and payment of fees. Late registration fee for those who register after 12:00 noon, May 28.
May 29	Wed.	First day of classes.
June 3	Mon.	Last day to register; last day to withdraw (or drop a course) with refund; last day to drop a course without a grade.
June 5	Wed.	*Deadline for submission of theses in final form to the Graduate School by candidates*

NOTE: Chairmen of doctoral advisory committees are reminded to schedule preliminary examinations for their students at least one semester before the anticipated date for scheduling the final oral examination.

		for master's and doctoral degrees in July, 1974. Last day for taking final oral examinations by candidates for master's degrees not requiring theses. Last day for filing application for admission to candidacy for students expecting to complete requirements for the master's degree in August, 1974.
July 2	Tues.	Last day of classes.
July 3	Wed.	Final examinations.
Second Session		
July 9-10	Tues.-Wed.	Opening days (counseling, advising, etc.).
July 11	Thur.	Registration and payment of fees. Late registration fee for those who register after 12:00 noon, July 11.
July 12	Fri.	First day of classes.
July 17	Wed.	Last day to register; last day to withdraw (or drop a course) with refund; last day to drop a course without a grade.
July 18	Thur.	*Deadline for submission of theses in final form to the Graduate School by candidates for the master's and doctoral degrees in August, 1974. Last day for taking final oral examinations by candidates for the master's degree not requiring theses.*
August 15	Thur.	Last day of classes.
August 16	Fri.	Final examinations.

NOTE: Chairmen of doctoral advisory committees are reminded to schedule preliminary examinations for their students at least one semester before the anticipated date for scheduling the final oral examination.

NORTH CAROLINA STATE UNIVERSITY

North Carolina State University is the center for scientific and technological education, research and extension in North Carolina. Created in 1887 by act of the North Carolina legislature as the state's land-grant institution, State was established primarily as a school of agriculture and mechanic arts. In the 80 years since its founding, however, its interests and responsiblities have been greatly broadened in response to the major scientific and technological demands of our rapidly changing world. While maintaining deep commitments to the agricultural and industrial interests of North Carolina, State has become a university of major academic and research dimensions with national and international programs.

State's organization includes eight undergraduate schools, the Graduate School and the Division of Continuing Education. A total of 75 degrees are offered at the undergraduate level; at the graduate level there are 62 master's and 41 doctoral degree programs offered. Graduate instruction was first offered at North Carolina State in 1893. The first doctoral degree was awarded in 1926.

The eight undergraduate schools at State are the Schools of Agriculture and Life Sciences, Design, Education, Engineering, Forest Resources, Liberal Arts, Physical and Mathematical Sciences and Textiles. The research, extension and instructional programs of these schools are supported and strengthened by several specialized divisions and offices including: the Institutes of Statistics and Water Resources, the Computing Center, the Agricultural and Industrial Extension Services, and the Agricultural Experiment Station with its 17 branch stations. State's facilities also include a minerals laboratory and a fisheries research station.

The North Carolina State campus, with adjoining research farms, covers 3,000 acres and is valued at about $100 million. There are 80 major University buildings, including classroom, laboratory and auxiliary facilities buildings. In addition to the Raleigh campus, State operates a number of agricultural research farms and extensive experimental forests.

Undergraduate enrollment at State is currently about 10,950; in the fall semester of 1971 the Graduate School enrolled 2,258 students. A large international student group representing 60 countries is presently studying at State.

The University faculty and professional staff numbers about 1,500 members, including a graduate faculty of 910.

For 1972-73, State's budget will be about $80 million. In order to accommodate the growing enrollment and increasing research requirements, North Carolina State University is pursuing a continuing program of building and acquiring new faculty and research staff. The present research expenditure is about $19 million annually. Current research appropriations, contracts and grants total more than $39 million.

State is contributing to international development through an economic and technical mission to Peru, special soils studies programs for Latin America, and cooperative projects with the University of Kabul, Afghanistan and the Institute of Technology at Kharagpur, India. Scores of international visitors, individual faculty work with universities in other countries and the large international student enrollment at State indicate the extent of the University's international involvement.

North Carolina State is accredited by the Southern Association of Colleges

and Schools and the North Carolina Association of Colleges and Universities. In addition, individual schools and departments are accredited by various associations in their respective fields. State holds memberships in the Association of State Universities and Land-Grant Colleges, the American Council of Education, the College Entrance Examination Board, the Council of Graduate Schools in the United States, the National Commission on Accrediting, the Oak Ridge Institute of Nuclear Studies and the Southern Association of Colleges and Schools.

THE GRADUATE SCHOOL

The Graduate School at North Carolina State University offers programs leading to masters degrees in 62 fields of study, the Doctor of Philosophy in 38 and the Doctor of Education in two. The Graduate School includes 910 faculty.

Graduate instruction at North Carolina State University is organized to provide opportunity and facilities for advanced study and research in the fields of agriculture and life sciences, engineering, forestry, physical and mathematical sciences, technological education and textiles. The purpose of these graduate programs is to develop in advanced students a more adequate comprehension of the requirements and responsibilities essential for independent research investigation. In all the graduate programs emphasis is placed upon a high level of scholarship rather than upon the satisfaction of specific course or credit requirements.

Exceptional facilities for graduate study are provided at North Carolina State University. New buildings furnish modern well-equipped laboratories for graduate study in specialized areas of agriculture and life science, engineering, forestry, physical and mathematical sciences, and textiles.

A high degree of cooperation and coordination exists between the graduate programs of the University of North Carolina at Chapel Hill, the University of North Carolina at Greensboro and North Carolina State University. This co ordination is effected through the Graduate Executive Council of the Consolidated University, composed of representatives of the administrative boards of these three institutions and the academic vice-president of the statewide University of North Carolina system.

The North Carolina Agricultural Experiment Station, the Department of Engineering Research and the Department of Physical Sciences Research are integral parts of the University. The staff, research facilities, equipment and field studies of these organizations contribute in a very important way to the graduate programs. The Institute of Statistics at North Carolina State makes available to graduate students unusual opportunities in this important phase of research study.

North Carolina State University is located in Raleigh, situated on the boundary separating the broad coastal plains on the east from the rolling terrain of the Piedmont on the west, about midway between the northern and southern boundaries of the state. Raleigh is 29 miles from the University of North Carolina at Chapel Hill and 26 miles from Durham, the home of Duke University. The libraries and other facilities of the three institutions make this area one of the important centers of research opportunity in the South.

The D. H. Hill Library

Library facilities at North Carolina State University include the main D. H. Hill Library and special libraries for the Schools of Design, Textiles, and Forest Re-

sources. The collections, totaling more than 600,000 volumes, have been carefully assembled to serve the educational and research programs of the University.

The D. H. Hill Library contains particularly strong research holdings in the biological and physical sciences, in all fields of engineering, agriculture and forestry. The 6,000 volume Friedrich F. Tippmann collection in the field of entomology and related biological sciences is one of the outstanding collections in the country. The collection of books and journals in the humanities and social sciences is especially helpful to undergraduate students.

The library's comprehensive collection of scientific journals emphasizes the major teaching and research interests at State; approximately 7,000 journals are received regularly. A large collection of state and federal government publications further strengthens the library's research material. The D. H. Hill Library is a depository for publications of the Atomic Energy Commission and the Food and Agricultural Organization of the United Nations, and has been a depository for U. S. federal documents since 1923.

The Textiles Library, located in Nelson Textile Building, contains outstanding holdings in the field of textiles and textile chemistry. It is regarded as one of the best textile libraries in the country. The School of Design Library, in Brooks Hall, has a fine collection of books, journals and slides in the areas of architecture, landscape architecture and product design.

As a further aid to graduate and faculty research, the library participates in an interlibrary loan program with the University of North Carolina at Chapel Hill, Duke University, Research Triangle Institute, IBM, Chemstrand, the Division of Environmental Health Services and the N. C. State Library in downtown Raleigh. A bus, arriving at State daily Monday through Friday, makes resources from these seven libraries available to State students and faculty. Among the materials available are approximately 14,000 scientific periodicals.

The D. H. Hill Library building has recently been expanded and remodeled for additional library seating and open shelf collections. An 11-story addition provides bookstacks for a 1,000,000 volume book collection, and greatly expanded research facilities, including carrels and study areas.

Among the many services offered by the library are orientation tours for faculty and graduate students and also lectures on library use to all new students. Comprehensive reference service is available almost all the hours the library is open. A variety of microtext readers and printers in the library and an extensive microfilm collection provide access to much important research material. A music listening room is equipped with listening machines for playing taped recordings. One of the most widely used services in the library is the Photocopy Service. Coin-operated machines plus two machines operated by staff provide a wide variety of photocopy service, including copy from microfilm. Machines may be used all hours the library is open.

Institutes

INSTITUTE OF STATISTICS

The Institute of Statistics is composed of two sections, one at Raleigh and the other at Chapel Hill. At North Carolina State, the Institute provides statistical consulting services to all branches of the institution, sponsors research in statistical theory and methodology, and coordinates the teaching of statistics at the undergraduate and graduate levels. The instructional and other academic

functions are performed by the Department of Statistics, which forms a part of the Institute.

WATER RESOURCES RESEARCH INSTITUTE

The Water Resources Research Institute is a unit of the Consolidated University and is located on the campus of North Carolina State University. The deans of the Graduate School, School of Engineering, and School of Agriculture and Life Sciences at North Carolina State University and two faculty members from the University of North Carolina at Chapel Hill serve as a board of directors. The Institute was established to promote a multidisciplinary attack on water problems, to develop and support research in response to the needs of North Carolina, to encourage strengthened educational programs in water resources, to coordinate research and educational programs dealing with water resources, and to provide a link between the state and federal water resources agencies and related interests in the University.

Research and educational activities are conducted through established departments and schools of the University. All senior colleges and universities of North Carolina are eligible to participate in the Institute's research program. Applications for research grants must be received by September 1 for the Matching Grants Program and February 1 for the Annual Allotment Program preceding the fiscal year for which funds are requested. Basic support for the Institute's program is provided by the Office of Water Resources Research, U. S. Department of the Interior, under the Water Resources Research Act of 1964 and appropriations from the State of North Carolina.

The Institute has sponsored a graduate minor in water resources which offers a strong water resources program with the major in any of the basic disciplines contributing to water resources planning, conservation, development and management. This capitalizes on the combined training resources of the Chapel Hill and Raleigh campuses of the University and offers these in an organized way to graduate students seeking interdisciplinary training in this important field. Additional information concerning the program is presented elsewhere in this catalog.

The Institute also sponsors research and educational symposia and seminars, encourages the development of specialized training opportunities, and provides a means for the continuing evaluation and strengthening of the University's total water resources program.

Special Laboratories and Facilities

ADULT LEARNING CENTER

The Adult Learning Center is an organizational unit in the School of Education at North Carolina State University and is an integral part of the research and development program of the School of Education.

Established in 1967, the Center is committed to seeking new ways and means for facilitating the intellectual growth and development of adults. The multidisciplinary activities carried out by members of the University faculty associated with the Center are addressed to comprehensive and rigorous studies of the most pressing needs and problems confronting adult education. Among the objectives of the Center is the provision of national leadership in the development and

implementation of experimental and demonstration projects which give promise of materially improving adult education programs. A major concern of the Center is the development and dissemination of packaged instructional materials and improved instructional methods which are capable of being institutionalized within operational adult education programs in public school systems.

The Center maintains on the campus of North Carolina State University an adult learning laboratory, the primary purpose of which is to further the use of programmed instructional materials with undereducated adults. Continuing research is conducted in the laboratory to determine the capacity of programmed instructional materials to raise effectively and efficiently the general educational level of marginally literate adults.

BIOLOGY FIELD LABORATORY

The Biology Field Laboratory is located just eight miles from the University campus and comprises a 20-acre pond, 180 acres of extremely varied vegetation types and a modern laboratory building. The latter contains two laboratories, one for class use and another principally for research, and quarters for a married graduate student who serves as custodian of the property. The many unique ecological situations found in this area make it ideal for use by advanced classes of most biological science departments. Likewise, the area is well adapted to a wide variety of research projects by faculty, graduate students and undergraduates because it varies in habitat from the aquatic community to a dry, upland forest. The laboratory facility makes possible many types of behavioral, physiological, ecological, taxonomic and limnological studies that could be accomplished only with great difficulty at other locations. Since the site is close to the campus and readily accessible, those investigators with campus duties may carry out long-term studies there even though frequent observations must be made. This is an asset most vital to the biological programs of the University.

COMPUTING FACILITIES

North Carolina State University, along with Duke University and the University of North Carolina at Chapel Hill, have jointly formed the Triangle Universities Computation Center (TUCC). This center, equipped with a very large computer located in the Research Triangle Park, provides the bulk of the computational capacity for the campus. A variety of services are available including high-speed teleprocessing of jobs for batch computing, remote job entry from a variety of terminals and interactive processing for low-speed terminals. The campus Computing Center also has an IBM System 360, Model 40 (256K with a 2314 disk system and two tape drives). It operates simultaneously as a high speed teleprocessing terminal to the TUCC computer and as a stand-alone computer. In addition, the Computing Center operates two medium-speed terminals; one in the School of Engineering and the other in the School of Physical and Mathematical Sciences. Many low-speed terminals (IBM 1050, IBM 2741, teletypes, etc.) are located in departments and projects throughout the campus.

Other computer installations are operated for special projects and services on the campus including smaller digital computers as well as extensive analog and hybrid facilities in electrical engineering, biomathematics and the School of Education.

One of the principal reasons for the development of the above computer configurations is to take care of the heavy graduate student training and research requirements on the campus. The present computer systems provide for a wide

range of computing needs in graduate training and research. Programming courses of both the regular credit type, as well as short courses, are offered by the Department of Computer Science and Computing Center personnel.

ELECTRON MICROSCOPE CENTER

The facilities of the Electron Microscope Center are available to all graduate students and faculty within the University for research purposes and to those students who wish only to obtain a general knowledge of electron microscopy techniques. A small plate charge is assessed when the Center is used for research by faculty and graduate students.

The Center is located in Gardner Hall in a suite of rooms designed specifically for electron microscopy. The Center currently houses two transmission electron microscopes, a Siemens Elmskop 1A and a Hitachi HS-8-B. In addition, the Center provides a specimen preparatory laboratory and a completely equipped darkroom.

Formal instructional courses are provided by the Center involving electron microscopic cytological techniques, use of transmission and scanning electron microscopes, related photographic techniques and interpretation of electron microscopic results. The Center is involved in the instructional units of several additional courses offered by the University. In addition, instructional tours are made available to secondary educational groups within the State.

HIGHLANDS BIOLOGICAL STATION

North Carolina State University is an institutional member of the Highlands Biological Station, Inc., an inland biological field station located at Highlands, North Carolina. The town of Highlands is in the heart of the Southern Appalachians at an elevation of 3,823 feet. The area has an extremely diverse and interesting biota and the highest rainfall in the eastern United States. The facilities are available throughout the year for pre- and post-doctoral research in botany, zoology, soils and geology. The laboratory building with research rooms and cubicles and the library are well equipped for pursuit of field research problems. Also, four cottages and a dining hall are located on the edge of a six acre lake. In addition to 16 acres surrounding the lake, the station owns several tracts of undisturbed forested land available for research. Research grants are available from the station, and the stipends are adequate to cover room, board and research expenses.

NUCLEAR SERVICE FACILITIES

Specialized nuclear service facilities are available to the University faculty, students and industry. The purpose of these facilities is to further the use of nuclear energy in engineering, scientific and public service programs. The facilities include: a 1 MW steady-state and pulse, pool-type, research reactor (PULSTAR) and a 10 kW training reactor (both with a variety of test facilities); a 50,000 curie multi-purpose Cobalt-60 gamma irradiation source which includes a controlled environment support unit; intermediate hot laboratories with hoods, junior caves and glove boxes; a neutron activation analysis and radioisotope laboratory; NaI and solid-state detectors; counting and photographic rooms; and pulsed neutron source. In addition, a new 50,000 sq. ft. Burlington Engineering Laboratories complex has been completed for the housing of the Departments of Nuclear

Engineering and Engineering Research with their associated offices and laboratories.

CENTER FOR OCCUPATIONAL EDUCATION

Administered by the School of Education, the Center for Research, Development, and Training in Occupational Education is a national research and development center, the mission of which is to improve through research and related activity the quality and quantity of occupational education for all persons and groups in a community. The total program is focused on problems underlying the development of adequate programs of occupational education.

The Center at North Carolina State University involves elements of the Schools of Agriculture and Life Sciences, Education, Liberal Arts, and Physical and Mathematical Sciences. Cooperating and participating departments include adult education, agricultural education, economics, statistics, guidance and personnel services, industrial and technical education, politics, psychology, and sociology and anthropology.

The total program of the Center includes research, developmental, and action or exemplary projects directed by senior members of the faculty. One of the special features of the Center is its Research Intern Program whereby Center graduate research assistants who are interested in preparing for positions as research specialists in occupational education or related fields, and who have completed all course requirements for the doctorate, may be employed as a full-time research assistant to conduct and manage a project related to one of the major thrusts of the Center. The Research Intern Program leads to the completion of requirements for the doctorate in adult education, economics, statistics, occupational education, psychology and sociology.

PESTICIDE RESIDUE RESEARCH LABORATORY

The Pesticide Residue Research Laboratory is a facility in the School of Agriculture and Life Sciences devoted to research on pesticide residues in animals, plants, soils, water and other entities of the environment of man. Although the laboratory is administered through the Department of Entomology, it serves the total needs of the school in cooperative research projects requiring assistance on pesticide residue analyses.

The laboratory functions as a focal point for residue research involving interdepartmental cooperation, but faculty in the laboratory also conduct separate research of their own interest on persistence and decomposition of pesticides in soils and plants, absorption and translocation in plants, distribution in the environment, and contamination of streams, estuaries and ground water.

The modern laboratory is equipped with the latest analytical instruments. Graduate study can be undertaken in any aspect of pesticide residues either in the Pesticide Residue Laboratory or in one of the cooperating departments.

REPRODUCTIVE PHYSIOLOGY RESEARCH LABORATORY

The Reproductive Physiology Research Laboratory administered through the Department of Animal Science includes four environmental control rooms designed to provide constant levels of air temperature, humidity and light for animals involved in studies on reproduction. Facilities and equipment are available for surgery, in vitro growth of embryos, isotope labeling in embryo metabolism and transfer of embryos between females.

Support for research at both the master's and the doctoral levels is available. Students may elect a comparative approach to a specific problem in mammalian reproduction, working with several species, or they may choose to work with a single species. Generally students select a problem associated with the identification of factors influencing early prenatal development, the endocrine control of ovarian function or some aspect of elucidation and control of aberrations in mammalian reproduction.

Cooperative research is possible between the laboratory and the Medical School or the Environmental Health Sciences Center (at the University of North Carolina at Chapel Hill) for those students desiring a broader training in the general area of reproductive physiology.

Students whose work is concentrated in reproductive physiology can major in either animal science or physiology with a minor in related disciplines.

SOUTHEASTERN PLANT ENVIRONMENT LABORATORIES

The Southeastern Plant Environment Laboratories operate as a cooperative association between North Carolina State University and Duke University with one unit, commonly called a phytotron, located on each campus. The laboratory is especially designed for research dealing with the response of biological organisms to their environment, and the high degree of control makes it possible to duplicate any climate from tropical rain forest to arid desert or arctic cold.

Research in the North Carolina State unit concentrates on agricultural problems encountered in the southeastern United States. However, the ability to control all phases of the environment allows inclusion of research dealing with space, pollution and tropical agriculture as well as basic physiological and biochemical investigations.

The facilities are available to the resident research staff, participants in North Carolina State's graduate research program and to domestic and foreign visiting scientists.

TRIANGLE UNIVERSITIES NUCLEAR LABORATORY

TUNL is a laboratory for research in nuclear structure. It is located on the campus of Duke University in Durham and it is staffed by faculty members and graduate students in the Departments of Physics of Duke University, the University of North Carolina at Chapel Hill and North Carolina State University. The principal tools of the laboratory are particle accelerators used to bombard target nuclei with an assortment of ions of accurately controlled energy and small energy spread. For example, protons can be accelerated to desired energies between a few hundred thousand electron volts and a bit over 30 million electron volts energy. The accelerators are three MeV and a four MeV Van de Graaff generator and a 15 MeV tandem Van de Graaff generator injected by a 15 MeV AVF cyclotron normally accelerating negative ions. An on line computer is used for data collection and analysis.

Personnel from NCSU are participating partners in the maintenance and use of the laboratory. Collaboration with personnel from the other two participating universities is encouraged.

This laboratory is the first to combine a cyclotron and tandem Van de Graaff generator the "Cyclo-Graaff." Successful operation began on December 28, 1968. The unusual physical facilities and the collaboration of personnel from the three universities make this a truly excellent, exciting laboratory.

Special Training Programs

INSECT PEST MANAGEMENT

Food production, control of disease and abatement of pollution are problems of national and international concern. Adequate food for burgeoning populations is a problem of increasing urgency, and insect pests comprise an important limiting factor. Insect control is also of strategic importance in combating arthropod-borne diseases of man as well as of his cultivated plants and domesticated animals. Pollution, a companion problem of food production and disease control, is increasing at an alarming rate, partly as a result of inadvisable pest control practices.

If a viable and aesthetically desirable environment is to be maintained, the materials and methods of pest control must be used carefully under the guidance of personnel possessing a thorough understanding of ecological principles. A program to train such personnel as pest management specialists, including assistantships, is available for graduate students with an adequate background in biological sciences, chemistry and mathematics. Ecology is fundamental to the pest management concept since populations, communities and ecosystems are of primary concern in this approach to the regulation of pest numbers.

Trainees will major in entomology but may choose from a wide selection of minors such as statistics, biomathematics, genetics, microbiology, zoology and ecology. Faculty with competencies there and with other related disciplines are available as advisors.

RESEARCH PROGRAM AT THE OAK RIDGE ASSOCIATED UNIVERSITIES

North Carolina State is one of the sponsoring institutions of the Oak Ridge Associated Universities at Oak Ridge, Tennessee. Through this cooperative association, North Carolina State's graduate research program has at its disposal the facilities and research staff at Oak Ridge National Laboratory. Extensive research programs are under way there on physical and biological effects of radiation, radioisotope utilization and many other areas of nuclear science and engineering. When master's and doctoral candidates have completed their resident work, it may be possible, by special arrangement, for them to do their thesis research at Oak Ridge National Laboratory. In addition, it is possible for the staff members of this University to go to Oak Ridge for advanced study in their particular fields.

Other Programs

THE TRIANGLE UNIVERSITIES CONSORTIUM ON AIR POLLUTION

Controlling the quality of the air we breathe is now clearly recognized as one of the major problems facing man in the decades ahead. This concern has now been expressed as a statement of national policy.

On January 5, 1970, agencies in North Carolina took a major step toward making the state an international center for research and training in the field of air pollution control. With encouragement from the Office of Air Programs of the Environmental Protection Agency, the state's three major universities, which are integral parts of the Research Triangle, created the Triangle Universities Consortium on Air Pollution (TUCAP). Representatives of the University of North

Carolina at Chapel Hill, North Carolina State University and Duke University at Durham signed the compact and set into motion a concerted effort to control a problem that threatens national disaster. Adding focus to their effort was the proximity of the two national agencies most immediately concerned—the Office of Air Programs of the Environmental Protection Agency and the National Institute of Environmental Health Sciences. Both are located within the Research Triangle.

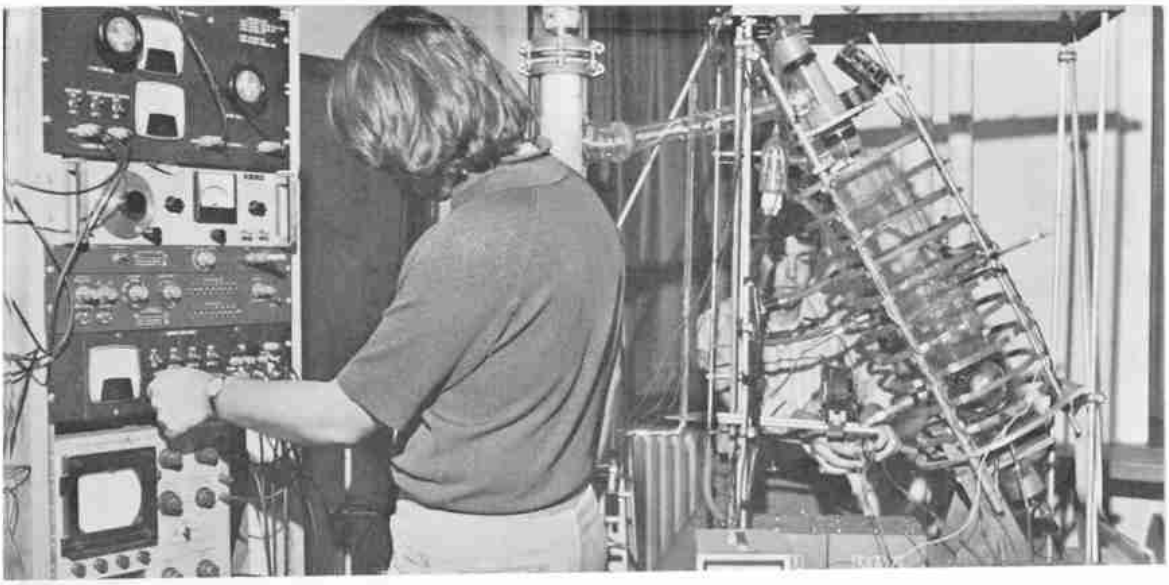
The Consortium is the first of its kind in the country. It has brought together institutions with long experience in working together on common problems and interests. A pool of talent and resources that could cover all facets of the national problem has been made available. From biology to ecology, from law to medicine, from engineering to economics, specialized knowledge has been brought together to provide the research and training needed by both the state and the nation.

TUCAP has already sponsored several conferences and symposia, developed joint instructional programs and stimulated considerable faculty involvement in air pollution related research on the three campuses. It is anticipated that major grant and contract funding will be channeled through TUCAP.

Controlled environmental studies are carried out in the Phytotron.

Marine Science students work at laboratories on the North Carolina coast.

Pulp and water become paper in the laboratories of the School of Forest Resources.



Plasma physics students investigate behavior of changed particle beams.

Loblolly pine studies in plant pathology utilize extensive greenhouse facilities.

Mice embryos are used in prenatal studies in the Reproductive Physiology lab.

New PULSTAR reactor in Nuclear Engineering.

Electron microscopes are used in teaching and research in agriculture and life sciences.

Catfish in a genetic study in zoology are caged at Yates Mill Pond.

The greenhouse range constitutes a valuable research and education complex.

Computer systems provide a wide range of services for graduate training and research.

Air pollutants effects on plants and trees are studied on the research farms.

Harrelson Hall in University Plaza is State's unusual round classroom building.

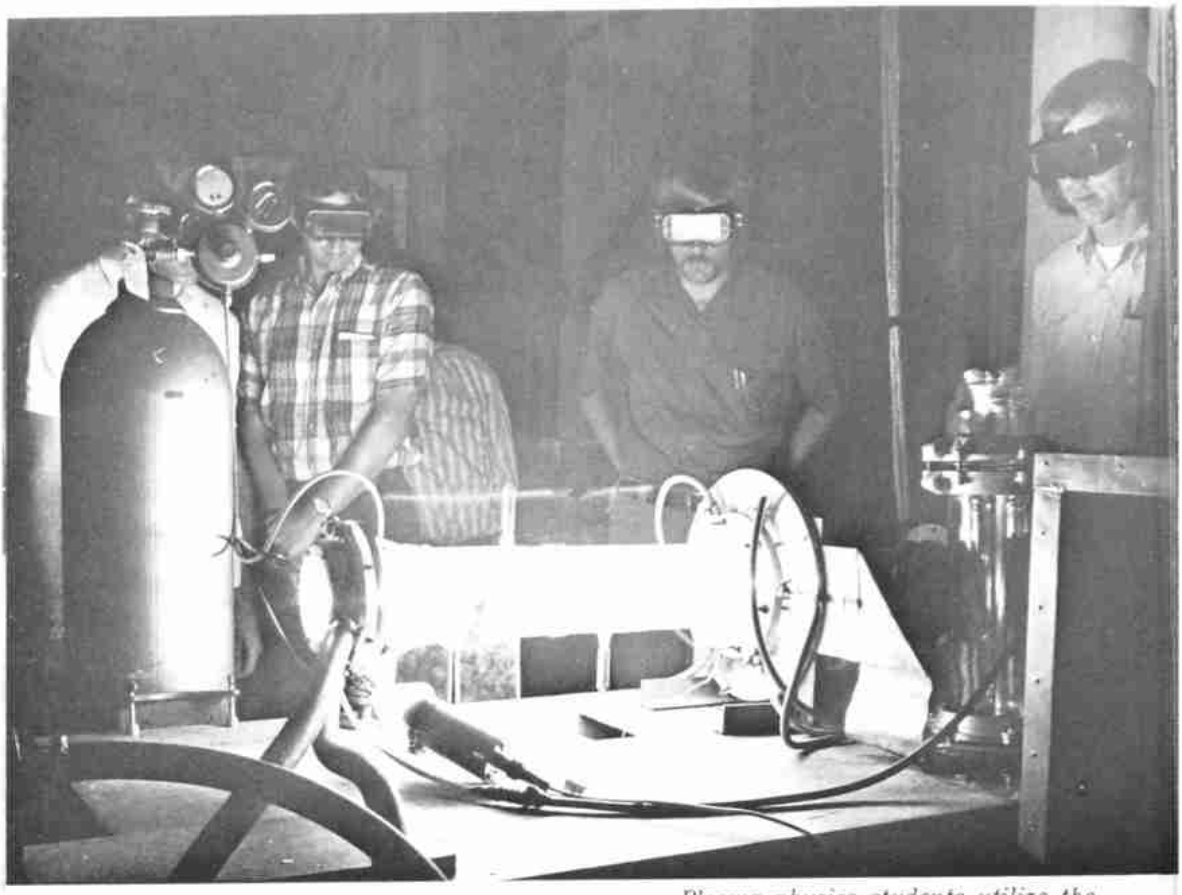
Artifacts add to a class on Asian religions.

The Ambilog - 200 is used for biomathematical research.

The School of Textiles equipment includes machines used in the processing of both natural and man-made fibers.

A sleep studies volunteer performs tasks in a chamber in the psychology department.

Urban design and architecture students study new metropolis projects.



Plasma physics students utilize the "linear pinch."

A concert at the University Plaza.

William Neal Reynolds Coliseum.

Concrete cylinder strength is tested in civil engineering lab.

University residence halls.

The effects of space on living organisms is studied in this genetics lab.

GENERAL INFORMATION

Admissions

Graduate School admission may be to full, provisional or unclassified status. Applications for admission to the Graduate School at North Carolina State University must be accompanied by official transcripts from all colleges or universities previously attended and should be received no later than one month before the start of the session in which enrollment is planned.

A non refundable application fee of $10.00 must be submitted with the application for admission to the Graduate School.

Since the Graduate Catalog is prepared to cover a two-year period, changes may occur during this period which are not included herein. In the event of such changes, the schools and departments concerned will communicate with applicants at the time that the application forms are received.

It is the prerogative of each school or department to require evidence of academic potential beyond those stated specifically in the catalog.

Judgments concerning admission or denial to particular degree programs and the criteria used for admission are initiated in the individual departments and schools. These criteria and judgments vary according to departments and schools and reflect not only estimates of ability of students to do graduate work but also the ability of the department to absorb additional graduate students.

Students of all races and sexes are equally welcome at North Carolina State University. All people may apply for and accept admission, confident that the policy and regular practices of the University will be administered without discrimination.

FULL GRADUATE STANDING

For admission in this category a student must have a bachelor's degree from a recognized college or university regarded as standard by a regional or general accrediting agency, and must have at least a "B" grade average in his undergraduate major.

PROVISIONAL ADMISSION

Provisional admission may be granted to applicants who lack undergraduate work considered essential for graduate study in the major field. Course work, without graduate credit, will be required to make up such deficiencies before admission to full graduate status can be granted.

Graduates from nonaccredited institutions may be granted provisional admission when their academic records warrant this status. Additional course work will be required of such students when deficiencies in their previous training are apparent.

Graduates from accredited institutions whose scholastic records are below the standards for admission to full graduate standing may be admitted provisionally when unavoidable extenuating circumstances affected their undergraduate averages or when progressive improvement in their undergraduate programs warrant provisional admission. All such students are required to take the Graduate Record Examination and to submit scores to the Graduate School

office in support of their application.* The National Teacher Examination may be substituted for the Graduate Record Examination if recommended by the department head. Information as to the dates on which the Graduate Record and the National Teacher Examinations are given may be obtained at the Graduate School office.

Many departments, although not normally requiring GRE scores, may in special instances require their submission as additional information to assist in making a judgment as to a student's chances of success in a graduate program.

Although some departments in the School of Education might consider the results of the National Teacher Examination as a basis for admission to the master's degree program, the Graduate Record Examination scores are required in all departments in the School of Education in the case of applicants for admission to doctoral programs.

Graduate students admitted to provisional status are not eligible for appointment to graduate assistantships or fellowships. They may attain full graduate standing when the deficiencies responsible for their provisional status are corrected. They also must have maintained a satisfactory academic record in all course work taken as part of their graduate program. Change from provisional to full graduate standing is effected only on written recommendation from the department in which the student is seeking his degree.

UNCLASSIFIED GRADUATE STUDENTS

Unclassified graduate students are not candidates for graduate degrees. They may take courses for graduate credit but may not apply more than 10 credits earned while in the unclassified status to any program leading to an advanced degree at this institution. Unclassified graduate students are expected to meet the same admissions requirements that apply to graduate students in full standing.

Applications for admission to the Graduate School should be on file in the Graduate School office at least 30 days in advance of the registration date for the term in which the student wishes to enroll in the Graduate School.

Public school personnel (primary teachers, secondary teachers or administrators) registering at North Carolina State for the first time who are interested primarily in "Certification Credit" may enroll as graduate students for a maximum of six semester hours without forwarding official transcripts of previous work to the Graduate Office. If, however, application is not made through normal channels for graduate credit in the session in which the course or courses are taken, the student will not be permitted to apply the credit toward an advanced degree at North Carolina State, or elsewhere.

In all cases where the teacher's interest is primarily in approval for certification credit, the School of Education will be responsible for assessing the adequacy of the teacher's qualifications for enrollment in the University in the particular course or courses. The School of Education will also be responsible for advising all such students early in each school session that if they wish their credits to be applied in due course to a higher degree at North Carolina State, or elsewhere, normal admission procedures will be required.

* Most of the advanced degree granting departments in the University strongly encourage submission of Graduate Record Examination scores. The following departments will not act on an application unless it is accompanied by GRE scores: biomathematics, English, fiber and polymer science, forest resources, guidance and personnel services, history, industrial and technical education (vocational industrial education and industrial arts education), mathematics, plant pathology, politics, psychology (requires the Advanced Test and Miller Analogies as well), sociology, textile chemistry (aptitude and advanced test in chemistry), textile technology (aptitude only) and zoology.

All teachers who have previously attended North Carolina State University and earned six semester hours of credit and wish to enroll for additional courses for graduate credit will be required to make application for admission to the Graduate School in the usual manner, if they have not already done so.

In all cases a "B" level of academic performance or better is required.

GRADUATE-SPECIAL

This classification is used primarily for students enrolling in special institutes such as the summer institutes regularly held for college teachers, high school teachers and graduate students, or special graduate training programs for separate groups such as our summer offerings for extension staff.

The following rules apply to students registered as graduate special:

1. All must have at least a baccalaureate degree from an accredited institution of higher learning;
2. Official transcripts need not be submitted to the Graduate Office for enrollment in this classification but the appropriate institute or program director must file with the graduate dean well in advance the nature of the program, the criteria and methods used in selection of the students, and assurances that the students have adequate preparation for the course contemplated;
3. Placement in this classification carries with it no implication that students will be admitted to the Graduate School in any of the other classifications;
4. Graduate credit will be allowed, not to exceed six hours of course work at the 500 or 600 level;
5. If the student is in due course admitted to the Graduate School, graduate credit obtained under this classification may apply to an advanced degree, if in the judgment of the advisory committee the course(s) is germane to the particular program of work, and performance was at an adequate level;
6. Students who have received as much as six hours of graduate credit under this classification must make application for admission to the Graduate School before permission will be granted to enroll for additional graduate work.

Registration

The Office of Registration must have written authorization from the dean of the Graduate School before any graduate student will be given a permit to register. This authorization will be sent to the Office of Registration by the graduate dean at the time the student is notified of his acceptance.

REGISTRATION FOR COURSES AT OTHER CAMPUSES OF THE CONSOLIDATED UNIVERSITY

Graduate students working toward an advanced degree at North Carolina State University may find it desirable to enroll for certain courses in one of the other campuses of the University (see page 13.) The following principles and procedures apply in such cases:

1. A graduate student shall be considered to remain in the Graduate School of the campus of the University to which he is admitted for a specific degree program, to be under the control of his department, to be advised by his department and to be enrolled by that Graduate School for any graduate work which he may take for credit in his own campus or any other campus of the University.

2. A graduate student at one campus of the University who is taking work at some other campus of the University for credit toward his degree at the University campus to which he has been admitted shall be enrolled for all courses, including those at the other campus of the University, in his home Graduate School. This Graduate School shall consider courses taken at the other campus of the University as a part of the student's normal load and shall use such enrollment in computing the total billing which the home University will make to the student.
3. A student at one campus of the University who is by this method enrolled in one or more graduate courses at some other campus of the University will be admitted to these courses, provided space exists in these classes, by the Graduate School of the other campus upon normal notification by the Graduate School of the student's campus that the student has been properly enrolled for these courses and has the approval of the home campus for this program of study.
4. During the summer sessions, approval of the courses to be taken shall be asked, but the billing procedures shall be those regularly used for visiting students.
5. No student enrolled as a regular graduate student in any campus of the University shall be admitted to courses at another campus of the University without the presentation by the student of written permission from the Graduate School of the campus to which the student was originally admitted.
6. The graduate programs of students enrolled at North Carolina State University are under the jurisdiction of the Graduate School of North Carolina State University.

PHYSICAL EXAMINATIONS

All regularly enrolled graduate students must take a physical examination preferably given by the family physician and the results recorded on forms provided by the University. When this is not done the examination may be given by the North Carolina State physician during registration for a fee of $10.

COURSE LOAD

A full-time graduate load is considered to be nine to 15 credits per semester (including audits). This course load restriction is made so that graduate students may have time for reading and contemplation well beyond the limits set for satis factory undergraduate work. In exceptional cases one or two additional credit hours may be added to the roster if necessary in order to get prerequisite work not taught in subsequent terms, provided the corresponding adjustment in course load is made in the other terms. Rosters with additional credit hours beyond 15 should be accompanied by a special note from the head of the major department indicating the reasons for the additional work.

Full-time faculty of instructor rank and above and other full-time employees of the University who hold membership in the Teachers' and State Employees' Retirement System may register for credit or audit one course in each semester and one course during one of the two summer sessions with free tuition privileges. Free tuition privileges apply only during the period of one's normal employment and do not include such other charges as registration, laboratory or other appropriate fees. Each applicant for free tuition privileges must complete and submit through regular administrative channels a form provided by the University. A maximum of eight semester hours may be taken during the academic year.

Employees having academic rank higher than that of instructor may register for graduate work for credit to be transferred to other institutions, but they may not undertake programs for graduate degrees at North Carolina State University.

Graduate assistants on half-time appointments are permitted a maximum course load of nine credits per semester unless corresponding adjustments are made in their service obligations during the same semester. If the appointment is for the academic year of nine months, half-time assistants are restricted to a maximum of 18 credit hours of work during the nine months of their appointment. Half-time graduate assistants whose appointments are for 12 months may not exceed a total of 24 credits during the 12-month period of their appointment. Three-quarter time graduate assistants whose appointments are for 12 months may register for a total of 16 credits during the calendar year. A total of six credits is the maximum load in a regular semester.

A member of the North Carolina State senior class may, upon approval of the dean of the Graduate School, register for courses in the 500 group for graduate credit to fill a roster of studies not to exceed 15 credits in any semester. No more than six hours of graduate credit may be acquired by an undergraduate student and the credits associated with courses approved for graduate credit may not apply toward the requirements for the bachelor's degree. Courses listed with numbers in the 600 series are not ordinarily open to undergraduates. Occasional exceptions may be made for "honor" students.

Tuition and Fees

SEMESTER RATES

For Academic Year 1971-1972

RESIDENTS OF NORTH CAROLINA				NONRESIDENTS			
HOURS	TUITION	REQUIRED FEES	TOTAL	HOURS	TUITION	REQUIRED FEES	TOTAL
1-3	$ 37.50	$99.00	$136.50	1-3	$216.50	$99.00	$315.50
4 6	75.00	99.00	174.00	4-6	433.00	99.00	532.00
7 or more	112.50	99.00	211.50	7 or more	650.00	99.00	749.00

For Academic Years 1972-1973, 1973-1974

RESIDENTS OF NORTH CAROLINA				NONRESIDENTS			
HOURS	TUITION	REQUIRED FEES	TOTAL	HOURS	TUITION	REQUIRED FEES	TOTAL
1-3	$ 37.50	$99.00	$136.50	1-3	$300.00	$99.00	$399.00
4-6	$ 75.00	99.00	174.00	4-6	600.00	99.00	699.00
7 or more	112.50	99.00	211.50	7 or more	900.00	99.00	999.00

REQUIRED FEES
1971-73

General Academic	$38.00
Medical	10.00
Athletic	10.00
Special	41.00

Eligibility of a non-resident for reduced tuition rates. Under certain conditions, students who have been solicited for a "special talent" and have been offered an assistantship, traineeship, or fellowship, may be eligible for reduced tuition

rates. A campus committee of the Administrative Board takes action on all such cases.

Initial Tuition Deposit: Each applicant for admission who is accepted by North Carolina State is required to remit to the University an advance deposit of not less than $100.00 to be applied against the student's tuition and fees for the academic term for which he has been accepted, said sum to be paid within three weeks of the mailing by the institution of the notice of acceptance; if the deposit is not paid within said period the applicant shall be assumed to have withdrawn his application. In the event of hardship, the deposit may be waived by the institution at its discretion. If the applicant, after remitting his deposit, decides not to attend the institution and gives notice of this decision by May 1, in the case of application for the fall term, or at least one month prior to the beginning of the term, in the case of application for the spring or winter term, the deposit shall be refunded. Deposits made by students who fail to give notice of withdrawal to the University as provided above shall be forfeited to the institution and shall be used to supplement appropriations for scholarships; provided, however, that any deposit shall be refundable if in the judgment of the University the withdrawal of an applicant is the result of illness, a call to military duty or other circumstances which are beyond the student's control and which the institution deems adequate.

Subsequent Tuition Deposits: An advance deposit of $50.00 is required to be made by each student enrolled for the regular academic year who intends to return for the succeeding academic year. The fee shall be paid during the last regular term of the academic year preceding the academic year for which the deposit is being paid. In the event of hardship, the deposit may be waived by the institution in its discretion. The deposit shall be applied against the student's tuition and fees in the event he returns. If he decides not to return to the institution and gives notice of his decision within 30 days after the last day of the term in which he made the deposit, or if the institution determines that he is not eligible to return, the deposit shall be refunded. Deposits made by students who fail to give notice of withdrawal as provided above shall be forfeited to the institution and shall be used to supplement appropriations for scholarships; provided, however, that any deposit shall be refundable if in the judgment of the institution the withdrawal of an applicant is the result of illness, a call to military duty, or other circumstances which are beyond the student's control and which the institution deems adequate.

Application Fee: A nonrefundable application fee of $10.00 is required to accompany each application for admission.

SPECIAL REGISTRATIONS AND FEES

Thesis Preparation Only: (GR 598 or GR 698)	
In-Residence ($19.00 plus $99.00 fees)	$118.00
Not-In-Residence ($19.00 plus $7.00 registration fee)	26.00
Dissertation Research: (GR 697)	
In-Residence ($19.00 plus $99.00 fees)	118.00
Not-In-Residence ($19.00 plus $7.00 registration fee)	26.00
Examination Only: (GR 597)	
In-Residence ($10.00 plus $99.00 fees)	109.00
Not-In-Residence ($10.00 plus $7.00 registration fee)	17.00

Audits: Registered and paying for other course work—one audit free.
Not registered for other course work rates same as for credit (in Summer Sessions, all audits are charged for as though they were being taken on a credit basis).

Full-time Faculty or Staff 7.00

Microfilming Doctoral Dissertation 21.00

Incidental fees and charges are levied for purposes and services available to all graduate students whether or not the student takes advantage of them.

The full amount of incidental fees and charges will be collected, notwithstanding the number of semester hours of credit for which the student may enroll.

In cases of occasional or part-time graduate students not in residence, application for cancellation of nonacademic fees may be made if it is clear that the student could not use the services covered. Application forms are available in the Graduate School and the Office of Business Affairs.

Full-time faculty of instructor rank and above and other full-time employees of the University who hold membership in the Teachers' and State Employees' Retirement System may register for credit or audit one course in each semester or one course during one of the two summer terms with free tuition privileges. Free tuition privileges apply only during the period of one's normal employment and do not include such other charges as registration, laboratory or other appropriate fees. Each applicant for free tuition privileges must complete and submit through regular administrative channels a form provided by the University. A maximum of eight semester hours may be taken during the academic year.

Faculty members on less than full-time appointments will be permitted to take more than one course per semester upon the recommendation of their dean and the approval of both the dean of the Graduate School and the Provost. In these cases tuition and fees will be the same as those for part-time graduate students computed at residence rates.

Maximum permissible course loads for graduate students holding part-time appointments are as follows: three-quarters time, six hours; half-time, nine hours; quarter-time, 12 hours.

Students wishing to visit classes without participation in class discussions, quizzes or examinations must register for this privilege as auditors. Visiting classes without registration is not permitted. Graduate students may register for one course as an audit in any semester without charge when the audit is certified by the dean of the Graduate School as a part of course work for which tuition charges are made (this does not apply in the summer sessions).

Graduate students often mistakenly assume that registration for an audit carries with it the privilege of irregular or infrequent attendance. This is not correct! When audits are recommended by departmental advisers or appear on the student's plan of work, regular attendance is expected as in courses taken for credit. Failure to attend on a regular basis will be so noted on the student's permanent record.

Audits in subjects in which the student has had no previous experience will be evaluated at full credit value in determining course loads. Audits taken as repetition of work previously accomplished are considered at one-half their credit value in calculating course loads. With the single exception of foreign language audits, all audit registrations must fall within the maximum permissible course loads. Audits are not permitted students registering for thesis preparation. While audit registrations are evaluated for purposes of determining permissive course loads in terms of

the above regulations of the Graduate School, the Office of Business Affairs considers all audits excepting the one permitted free of charge, in terms of full credit value in calculating the tuition for graduate students.

Dissertation Research: A Ph.D. student whose program of work specifies no formal courses during a given semester or summer session, who has successfully passed his preliminary examinations, completed at least six hours of departmental research on his Ph.D. program and who is devoting full time to his dissertation research shall register for "dissertation research" or an appropriate research course offered by the department. A graduate student so registered will be classified as a full-time student. "Dissertation research" as is the case for "thesis preparation" will have no credit hour designation. Tuition and fee charges for "dissertation research" are the same as those for "thesis preparation."

Thesis Preparation: Graduate students who have completed all course work, research and residence requirements and who are writing a thesis or dissertation may register for "thesis preparation." The tuition charge for this registration is $19.00. Students registering for thesis preparation will pay, in addition, fees of $99.00 per semester. When not in residence these charges will be $19.00 plus $7.00 registration fee or $26.00.

Examination Only: Graduate students in master's programs not requiring a thesis, who have completed all requirements except the final oral examination by the beginning of the semester in which the degree is to be awarded, will be required to register for "examination only." The tuition charge for this registration is $10.00. Students registering for examination only will pay, in addition, fees of $99.00 per semester. When not in residence these charges will be $10.00 plus $7.00 registration fee or $17.00.

Microfilming Fees: A fee of $21.00 is charged all doctoral candidates for microfilming their dissertations.

Anyone who feels a mistake has been made in his bill should consult the Office of Business Affairs.

All tuition charges and fees are subject to change without notice.

TUITION AND FEES FOR PART-TIME STUDENTS*—SEMESTER RATE

RESIDENTS OF NORTH CAROLINA				NONRESIDENTS			
HOURS	TUITION	REQUIRED FEES	TOTAL	HOURS	TUITION	REQUIRED FEES	TOTAL
1-3	$37.50	$12.50	$ 50.00	1-3	$216.50	$12.50	$229.00
4-6	75.00	25.00	100.00	4-6	433.00	25.00	458.00
7 or more	Cannot be classified as part time if enrolled for more than six (6) hours.			7 or more	Cannot be classified as part-time if enrolled for more than six (6) hours.		

* Part-Time students are defined as persons who are primarily employed (full-time and permanent), registered for not more than six hours during the regular semester as incidental students. Part-time students must complete an "Application for Cancellation of Nonacademic Fees" form each semester to qualify for the reduced rates. See schedule 9.

FEES FOR SUMMER SCHOOL

	1972	1973
Registration Fee	$27.00	$27.00
Tuition (in state students per credit hour)	10.00	10.00
Tuition (out of-state students per credit hour)	37.50	50.50
Audits (same as for credit)		

REFUND OF TUITION AND FEES

A student who withdraws from school on or before the first two weeks of a semester will receive a refund of the full amount paid less an enrollment fee. After the period specified, refunds may be obtained only by submitting a petition to the Refund of Fees Committee, which endeavors to protect the rights of the student and the University. The committee is empowered to approve a petition when the withdrawal is caused by extensive illness and upon the advice of a physician, military orders or when circumstances justify waiving the rules. For information, contact William R. Styons, Director of Student Accounts, "B" Holladay Hall.

RESIDENCE STATUS*[(a)]

General: The tuition charge for legal residents of North Carolina is less than for nonresidents. To qualify for in state tuition, a legal resident must have maintained his domicile in North Carolina for at least the 12 months next preceding the date of first enrollment or reenrollment in an institution of higher education in this state.[b] Student status in an institution of higher education in this state shall not constitute eligibility for residence to qualify said student for in-state tuition.

Minors: A minor is any person who has not reached the age of 18 years.[c] The legal residence of a person under 18 years of age at the time of his first enrollment in an institution of higher education in this state is that of his parents, surviving parent or legal guardian. In cases where parents are divorced or legally separated, the legal residence of the father will control unless custody of the minor has been awarded by court to the mother or to a legal guardian other than a parent. No claim of residence in North Carolina based upon residence of a guardian in North Carolina will be considered if either parent is living unless the action of the court appointing the guardian antedates the student's first enrollment in a North Carolina institution of higher education by at least 12 months.

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*[(a)]These regulations, as amended on August 13, 1971, shall be applicable with respect to tuition payments coming due after said date.

[b]The reference in this sentence to "twelve months" formerly read "six months"; Chapter 845 of the 1971 Session Laws, which was ratified on July 13, 1971, made the change from "six months" to "twelve months." The office of the Attorney General has rendered the following opinion:

"The eligibility of all students who have applied and have been accepted by state-supported institutions of higher education prior to July 13, 1971, shall be determined upon the individual having maintained his domicile in North Carolina for at least the six months next preceding the date of first enrollment or reenrollment in an institution of higher education in this State. The twelve-month requirement as provided for in Chapter 845 of the 1971 Session Laws does not apply to any individual who applied for admission and was accepted by a state-supported institution of higher education prior to July 13, 1971. The student already enrolled as an in-state student, qualifying as such by compliance with the six month requirement prior to July 13, 1971, shall retain in-state status."

[c]Chapter 585 of the 1971 Session Laws, which became effective on July 5, 1971, changed the age of adulthood from 21 years to 18 years.

Adults: An adult is any person who has reached the age of 18 years. Persons 18 or more years of age at the time of first enrollment in an institution of higher education are responsible for establishing their own domicile. Persons reach ing the age of 18, whose parents are and have been domiciled in North Carolina for at least the preceding 12 months, retain North Carolina residence for tuition payment purposes until domicile in North Carolina is abandoned. If North Carolina residence is abandoned by an adult, maintenance of North Carolina domicile for 12 months as a non-student is required to regain in state status for tuition payment purposes.

Married Students: The legal residence of a wife follows that of her husband, except that a woman currently enrolled as an in-state student in an institution of higher education may continue as a resident even though she marries a nonresident. If the husband is a nonresident and separation or divorce occurs, the woman may qualify for in state tuition after establishing her domicile in North Carolina for at least 12 months as a non-student.

Military Personnel: No person shall lose his in-state resident status by serving in the Armed Forces outside of the State of North Carolina. A member of the Armed Forces may obtain in state resident status for himself, his spouse or his children after maintaining his domicile in North Carolina for at least the 12 months preceding his or their enrollment or reenrollment in an institution of higher education in this state.

Aliens: Aliens lawfully admitted to the United States for permanent residence may establish North Carolina residence in the same manner as any other nonresident.

Property and Taxes: Ownership of property in or payment of taxes to the State of North Carolina apart from legal residence will not qualify one for the in-state tuition rate.

Change of Status: The residence status of any student is determined as of the time of his first enrollment in an institution of higher education in North Carolina except: (a) in the case of a nonresident student at the time of first enrollment who has subsequently maintained domicile as a non-student for at least 12 consecutive months and (b) in the case of a resident who abandons his legal residence in North Carolina.

In either case, the appropriate tuition rate will become effective at the beginning of the first subsequent term enrolled.

Responsibility of Students: Any student or prospective student in doubt concerning his residence status must bear the responsibility for securing a ruling by stating his case in writing to the admissions officer. The student who, due to subsequent events, becomes eligible for a change in classification, whether from out-of-state to in-state or the reverse, has the responsibility of immediately informing the Office of Admissions of this circumstance in writing. Failure to give complete and correct information regarding residence constitutes grounds for disciplinary action.

Appeals of Rulings of Admission Officers: Any student or prospective student may appeal the ruling of the admissions officer in writing to the Chancellor of the

institution. The Chancellor may use any officer or committee which he deems appropriate in review of the appeal. Appeal of the Chancellor's ruling may be made to the President of the University of North Carolina; such appeals to be filed with the Chancellor and forwarded by him to the President.

Fellowships and Graduate Assistantships

FELLOWSHIPS

Graduate fellowships and traineeships provide funds to graduate students to assist in the support of their programs of advanced study. Holders of fellowships have no service obligation to the University and may devote full time to their graduate programs.

Some of the agencies sponsoring fellowships at North Carolina State University are the Agency for International Development, Aluminum Company of America, the Atomic Energy Commission, Chemstrand, Douglas Aircraft Company, Dow Chemical Company, DuPont Company, E. Sigurd Johnson, Eastman Kodak Company, Ford Foundation, General Electric Foundation, General Food Corporation, Goodyear Tire and Rubber Company, Honor Society of Phi Kappa Phi, International Institute of Education, Kellogg, National Aeronautics and Space Administration, National Institutes of Health, National Lumber Manufacturing Association, National Science Foundation, North Carolina Grange (E. G. Moss Fellowship), North Carolina Textile Foundation, Office of Education (Department of Health, Education, and Welfare), Phillips Petroleum Company, Public Health Service (U. S.), R. J. Reynolds Tobacco Company, Research Corporation, Rockefeller Foundation, Scholler Foundation, Shell Companies Foundation, and Wachovia Bank and Trust Company.

Information relative to stipends, areas of research study supported by specific fellowships, and application forms may be obtained from the Graduate School or from the heads of the appropriate departments.

ASSISTANTSHIPS

Graduate assistantships are granted to selected students who normally devote half-time to service duties for the University. Teaching assistantships carry stipends ranging from $2,900 to $3,800 for the academic year and permit the holder to enroll for 60 percent of a full course load. The stipends for research assistantships range from $2,900 to $3,800 for a calendar year appointment.

The University offers 713 assistantships requiring a service obligation in either teaching or research. Some of these are supported by funds granted by the following agencies: the Air Force Cambridge Research Laboratories, Air Force Office of Scientific Research, the American Museum of Natural History, American Potash Institute, Army Missile Command, Army Research Office (Durham), the Atomic Energy Commission, Best Foods, Bureau of Commercial Fisheries, Campbell Soup Company, the Chilean Nitrate Education Bureau, Inc., Cotton, Incorporated, Gerber Products Company, Graham Manufacturing Company, Hercules Powder Company, Department of Labor, the Lilliston Implement Company, The Lilly Company, National Aeronautics and Space Administration, E. I. Dupont de Nemours and Company, National Institutes of Health, National Knitwear Manufacturers Association, National Science Foundation, North Carolina Agricultural Foundation, North Carolina Board of Science and Technology, North Carolina Dairy Foundation, North Carolina Milk Commission, North Carolina Motor Carriers Association, Owens-Corning Fiberglass Corporation, Pacific Coast Borax

Company, Peanut Growers Association, the Petroleum Research Fund of the American Chemical Society, Pulp and Paper Foundation, Inc., R. J. Reynolds Tobacco Company, the Ralston-Purina Company, the Solvay Process Division of Allied Chemical Company, Sherwin Williams Foundations, Southeastern Association of Game and Fish Commissions, the Tennessee Corporation, Southern Forest Institute, The Union Camp Corporation, U. S. Department of the Interior, U. S. Office of Education, U. S. Public Health Service and the Weyerhaeuser Foundation.

Students interested in applying for a fellowship or assistantship may indicate their interest on the application forms submitted.

Other Financial Aid

LONG-TERM, LOW-INTEREST LOANS

Graduate students who are American citizens are eligible for consideration for long-term, low-interest loans. Applications are made to the Financial Aid Office, 205 Peele Hall. To qualify, a student must demonstrate clear financial need and must be making satisfactory progress academically.

National Defense Student Loans: Graduate students may qualify for up to $2,500 per year in loans from this source, with a cumulative maximum of $10,000. Interest at three percent begins to accrue and repayment of principal begins nine months after the student's last enrollment for at least half-time college study. Repayment may be extended over a 10-year period. For the most part, long-term loans are approved as supplementary to fellowships and assistantships. A student is expected to accept an assistantship, if one is available, before seeking loan help.

Institutional Long Term Loans: Loans are also made from University funds on essentially the same terms as under the National Defense Student Loan program.

Federal Guaranteed Loan Program: This program provides for loans from private lenders, with interest paid by the federal government in cases of medium or small family income. Graduate students may borrow up to $1,500 per year with an aggregate limit of $7,500. Application procedures differ with state of residence. A North Carolina resident obtains forms at the financial aid office of the institution which he is attending and submits them through the financial aid office to the College Foundation, Inc., which acts as the agency for most private lenders in North Carolina who participate.

COLLEGE WORK-STUDY PROGRAM

Work-study jobs under a federal program are available to graduate students as well as undergraduates. Again, however, the graduate student is expected to accept an assistantship in preference if one is available. The same application procedure and eligibility requirements are in effect as is the case with National Defense and institutional long-term loans. In fact, consideration for both or either kind of financial aid is obtained by one application. Available jobs are normally on campus. The student is limited to 15 hours per week while attending classes and to 40 hours per week during vacation periods. Rates of pay vary; each job awarded is given an approximate dollar value.

SHORT-TERM EMERGENCY LOANS

Usually in amounts of $100 or less, loans to be repaid within 30 to 60 days may be obtained on short notice at the Financial Aid Office. Students are asked to limit such requests to actual emergency situations in which alternative sources of funds are unavailable.

Housing

North Carolina State University strives to provide suitable accommodations for its students. The University operates 14 residence halls for 4,863 men; two residence halls for 800 women; 300 apartments for married students; and 12 on campus fraternity houses for 480 men.

RESIDENCE HALLS—ROOM ASSIGNMENTS

Rooms in residence halls are reserved in the order in which applications are received as long as space is available. Full payment of the semester rent, $133 for men and $158 for women, is required to reserve a room. Initial housing applications are mailed with acceptance notifications and indicate the date the rent is payable.

Rooms are assigned for each semester rental period. Students may reserve the same room for succeeding semesters. Foreign students are permitted to rent rooms during the summer although they may not be full-time students or involved in university-connected services.

REFUND OF ROOM RENT

If a room reservation is cancelled at the Housing Rental Office, Leazar Hall, in person or in writing on or before August 15th for fall semester and December 15th for spring semester (the date of cancellation is the date notification is received in that office), the rent paid will be refunded less a $25 reservation fee which is non-refundable if a student is eligible to register. Between August 15th (for fall semester) and the last day to withdraw with tuition refund, and between December 15th (for spring semester) and the last day to withdraw with tuition refund, no refund will be made for any reason other than failure to register or official withdrawal from the University. During these times and for the above stated reasons, the rent paid will be refunded less the $25 reservation fee and a daily charge of $2.00 per day for men and $2.25 per day for women from the first day of classes until the room is vacated. Students who fail to notify the Housing Rental Office and who fail to check in and secure their keys on or before 5 p.m. the first day of classes will have their reservation cancelled without refund.

FURNISHINGS AVAILABLE

Rooms are furnished with beds, mattresses, chairs, study tables, dressers and closets. The student must bring his own study lamp if not assigned to Bragaw, Carroll, Lee, Metcalf or Sullivan Halls. Linen, blankets and pillows are available through the linen rental service operated by the Auxiliary Services Office. Laundry rooms with washers and dryers are located in the women's residence halls.

The residence halls are not equipped with kitchen facilities for meal preparation.

HOUSING FOR MARRIED STUDENTS

The University operates 300 apartments (McKimmon Village) for married students. The rental is $49 for an efficiency; $59.50 for a one-bedroom; and $71 for a

two-bedroom, including water only. Priority in renting goes to graduate students. Information on availability and applications should be requested from the Housing Rental Office, North Carolina State University, Box 5505, Raleigh, N. C. 27607.

The University does not operate a trailer parking area; however, privately owned parks are available within a reasonable distance of the campus.

Raleigh has numerous privately owned apartments and houses available for rent to university students. A partial listing is located in the Housing Rental Office. No listing is published because of the rapid turnover.

FOOD SERVICES

Food service is provided at two conveniently located facilities—Erdahl-Cloyd Union and Harris Cafeteria. Cost depends on the individual's requirements and the selection of food. A typical student, paying cash for each meal, will spend approximately $500 per academic year.

The Students Supply Stores operate soda fountain snack bars for the convenience of resident students in five areas. There is an additional snack bar located in the Nelson Textile Building.

LINEN RENTAL SERVICE

The linen service provides for the initial issue of two sheets, one pillow case and three towels. The student may exchange his linen weekly at a cost of $20 per year. Pillows may be rented for $1.50 per year. A regular blanket rents for $3 per year and the N. C. State monogrammed blanket rents for $5. These services are available to both campus and off-campus students. Application may be made in the Auxiliary Services Office in Holladay Hall.

GRADUATE DEGREES

Admission to the Graduate School does not constitute admission to candidacy for a graduate degree. Application for admission to candidacy for graduate degrees must be submitted to the Administrative Board of the Graduate School. Applications of students preparing for the master's degree may not be filed before the satisfactory completion of one full semester of graduate study and must be presented before the end of the first week of the last semester in residence. Approval of the application will be determined by the quality of the scholastic record and on the certification by the major department that the student is qualified to continue advanced work. Admission to candidacy for the doctorate is granted upon satisfactory completion of the qualifying or preliminary examinations.

The Graduate School at North Carolina State University offers work leading to the Master of Science degree and the Professional Master's degree in certain specialized fields in the Schools of Agriculture and Life Sciences, Design, Education, Engineering, Forest Resources, Physical and Mathematical Sciences, and Textiles; and the Doctor of Philosophy degree in certain fields of agriculture and life sciences, engineering, forest resources, physical and mathematical sciences, and textiles. The Doctor of Education degree, providing majors in adult education or occupational education, is offered in the School of Education. Work leading to the Master of Arts degree is offered in economics, English, history and politics.

A graduate student is expected to familiarize himself with the requirements for the degree for which he is a candidate and is held responsible for the fulfillment of

these requirements. This applies to the last dates on which theses may be accepted, the dates for examinations, the proper form of theses and all other matters regarding requirements for degrees.

Master of Science and Master of Arts Degrees

The Master of Science degree is awarded by North Carolina State University after a student has completed a course of study in a specialized field in agriculture and life sciences, education, engineering, forest resources, physical and mathematical sciences, or textiles, has completed a satisfactory thesis and has taken comprehensive examinations in the chosen field of study.

A Master of Arts degree is awarded in economics, English, history and politics. Candidates for Master of Science or Master of Arts degrees are expected to achieve high levels of scholarship. Graduate study is distinguished from undergraduate work by its emphasis upon independent research. The graduate student is more interested in the significance of facts than in the accumulation of data. He is concerned with the materials of learning and the organization and interpretation of these materials.

A graduate student's program of study is planned so as to provide a comprehensive view of some major field of interest and to furnish the training essential for successful research in this field and related areas of knowledge. As great a latitude is permitted in the selection of courses as is compatible with a well-defined major interest. The program of course work is selected with the object of making possible a reasonable mastery of the subject matter in a specialized field. Training in research is provided to familiarize the student with the methods, ideals and goals of independent investigation. Since there are many possible combinations of courses, the administration of graduate programs calls for personal supervision of each student's plan of work by a special advisory committee of the graduate faculty. The program of course work to be followed by the student as part of the requirements for the master's degree, and the thesis problem selected, must be approved by the student's advisory committee and the dean of the Graduate School.

Students are generally discouraged from seeking duplicate graduate degrees.

CREDITS

1. For the Master of Science degree or the Master of Arts degree a minimum of 30 semester hours is required.
2. No more than six of the academic credits required for the degree will be accepted from other institutions.
3. No graduate credit will be awarded for excess undergraduate credit from another institution.
4. All work credited toward a master's degree must be completed within six calendar years.
5. No graduate credit is allowed for courses taken by correspondence.

Normally, a maximum of six semester credits may be obtained in extension study in the field of education, provided the extension courses are taught by a member of the graduate faculty and provided the courses are given graduate ranking by the Graduate School. If a student has been admitted to the Graduate School and an approved program of work has been submitted, then six *additional* semester credits may be attained in off-campus graduate courses to apply to a minimal 30-hour

master's program. Credit for extension courses reduces the amount of credit that may be transferred from other institutions.

The 30 semester hour requirement for the master's degree represents the mini mum quantity of work acceptable. The credit hours required of graduate students usually exceed the minimum requirements. Inadequate preparation and thesis research frequently make additional work necessary.

COURSES OF STUDY

In a typical minimal program of 30 hours, at least 20 semester hours must come from the 500- and 600-level group with no less than six hours being at the 600 level. The program of the student may include no more than six hours of research nor more than two hours of departmental seminar unless the total program planned exceeds 30 hours. Courses at the 400 level counted toward the minimal 30 hour requirement may not ordinarily come from the major field.

During the first term in residence an advisory committee of at least three faculty members, one representing the minor field, will be appointed by the dean, after consultation with the head of the major department, for each student engaged in a program of work leading to the master's degree. The advisory committee will meet with the student and prepare a program of course work to meet the require ments of the student's graduate objectives. Four copies of the program, prepared on forms provided for this purpose, must be approved by each member of the committee, by the head of the major department and by the dean of the Graduate School. After approval in the Graduate Office, three copies will be returned to the department head—one for his files, one for the chairman of the advisory committee and one for the student.

The courses taken by a graduate student shall constitute a well-rounded but unified plan of study. This means that the program of research and course work shall be divided between a major and a minor field. While there are no inflexible rules which govern the number of credit hours that must constitute the major and minor, in general, it is expected that approximately two-thirds of the course work will fall in the major and one-third in the minor. The detailed course requirements for each graduate student program are left to the judgment of the advisory committee.

RESIDENCE

Students engaged in a course of study leading to the Master of Science or Master of Arts degree are required to be in residence, pursuing graduate work, one full academic year.

CLASS WORK

A graduate student is expected to show greater initiative in exploring the possibilities of the subject matter presented in the courses he takes than is the undergraduate. He is also expected to recognize the significance of facts and to assume a responsibility for relating data to theoretical concepts. In preparation, attendance and in all the routine of class work the graduate student is subject to the regulations observed in other divisions of the University.

GRADES

A minimum grade of "C" must be made on all formal course work to obtain graduate credit. An average of "B" must be obtained on all course work taken as part of the student's graduate program. Failure to maintain a "B" average will

place the student on probation. Any student whose academic record fails to meet the "B" average requirements for two consecutive terms will not be permitted to continue a graduate program without the written approval of the graduate dean.

Grades in research, seminar and special problems courses are given in terms of "S" (satisfactory) or "U" (unsatisfactory) in place of the symbols used for formal course work.

"S" and "U" grades in graduate courses are not used in computing GPA. However, in the case of a "U" grade, the student's advisory committee is notified immediately and asked to make recommendations. It may recommend (1) a repeat of the course, (2) the substitution of another course (with an "S", "A", or "B" grade required), or (3) if the course is not needed to fulfill degree requirements and if the student has otherwise completed an adequate program, the committee may request that no corrective action be taken in the way of course addition or substitution. The "U" grade will, however, remain on the record.

The grade *incomplete* may be used in research and laboratory courses when circumstances beyond the control of the student have prevented completion of the work by the end of the academic term. A grade of *incomplete* may be given only after approval of the graduate dean and must be converted to one of the usual symbols before the end of the next academic semester in which the student is in residence.

LANGUAGE REQUIREMENTS

Since this catalog is prepared for a two-year period covering the calendar years 1972-74, some departments may seek a modification of their language requirements during that period. Thus, a student would be well advised to inquire about this matter from the department in which he plans to work toward an advanced degree.

A reading knowledge of at least one modern foreign language (Germanic, Romance or Slavic) is presently required of candidates for the Master of Arts degree in English, history or politics, and by some departments for the Master of Science degree. Departments having this requirement are: biomathematics, chemistry, entomology and statistics. The School of Forest Resources and the Departments of Guidance and Personnel Services, Sociology and Soil Science leave the decision to the student's advisory committee.

In those instances where the language is required, the requirement must be satisfied before a student can be admitted to candidacy.

Proficiency in languages is determined by the Department of Modern Languages:

1. By traditional reading knowledge examination at any time requested by the student.
2. By taking course work (audit) especially designed for graduate students who have no previous foreign language experience or who wish to refresh work formerly done. The department offers special courses beginning with elementary grammar and proceeding, during the semester, to general professional reading. Pronunciation is emphasized to the degree in which it will help in translating from the language into English. This first course is followed by a second course in which the student selects work from publications touching as nearly as possible his major interest. He will then be assigned a particular instructor with whom he will read in individual conferences. When the conference instructor is satisfied that the student has

demonstrated his knowledge of intricate grammatical problems, a decrease in the time required for reading and a confidence in his ability to use the language, he will be certified without further examination. The completed translations may then, depending upon their merit, be edited and prepared for permanent filing with the various translation libraries throughout the country.

Graduate students who expect to complete the requirements for the Master of Science or Master of Arts degree should confer with the head of the Department of Modern Languages soon after registration to formulate plans for meeting the language requirement of the degree.

Students whose native language is other than English may meet the foreign language requirement by demonstrating a satisfactory mastery of English. Examinations in English are conducted by the Department of Modern Languages.

When only one language is required in a student's program, certification for that language must occur on this campus.

THESIS

A candidate for the Master of Science or Master of Arts degree must prepare a thesis representing an original investigation. The subject of the thesis must be approved by the head of the department in which the major work is done and by the student's advisory committee. Three copies of the thesis in final form, and five copies of the abstract, must be filed in the Graduate Office at least one month before the degree is awarded. Detailed instructions as to form and organization of the thesis may be obtained at the Graduate Office.

EXAMINATIONS

All candidates for the Master of Science or Master of Arts degree must pass, with a grade of "A", "B" or "C", all formal course work specified as part of the requirements for the degree. Graduate credit for research, seminar and special problems courses is granted when a grade of "S" is recorded in the Registration Office. In addition, the candidate must pass a comprehensive oral examination that is held to satisfy the examining committee that the candidate possesses a reasonable mastery of knowledge in the major and minor fields and that this knowledge can be used with promptness and accuracy. This examination may not be held until all other requirements, except completing the course work of the last semester, are satisfied. Application for the comprehensive oral examination must be filed with the graduate dean by the chairman of the advisory committee at least two weeks prior to the date on which the examination is to be held.

The oral examination will be conducted by an examining committee appointed by the graduate dean. The chairman of the examining committee will be the chairman of the student's advisory committee. At least two additional members will be appointed to represent the major and minor fields. The comprehensive oral examination is open to all graduate faculty members who care to attend but the decision as to the candidate's fitness rests solely with the examining committee.

At the discretion of the examining committee, written examinations covering the subject matter in the major and minor fields also may be required of the candidate. Written examinations, when required, normally should not be held earlier than the end of the first month of the last semester in residence and not later than one week before the comprehensive oral examination. Information as to when written examinations are scheduled should be obtained from the appropriate departments. See Summary of Procedures for the Master's Degree, pages 49-52.

Master's Degree in a Designated Field

This degree differs from the Master of Arts or Master of Science degree primarily in that course work is substituted for the thesis requirement. Very often this degree is sought by students who are interested in a wider variety of courses than can be chosen by a student who wishes research training at the master's level. A student may develop a program of study which terminates at the master's level or which may lead to further study toward the doctorate degree.

Following is a listing of the types of degrees that may be awarded upon completion of the course of study in a designated field.

Master of Education (Adult and Community College Education)
Master of Agriculture
Master of Education (Agricultural Education)
Master of Architecture
Master of Biological and Agricultural Engineering
Master of Biomathematics
Master of Chemical Engineering
Master of Civil Engineering
Master of Economics
Master of Electrical Engineering
Master of Engineering Mechanics
Master of Statistics
Master of Forestry
Master of Education (Guidance and Personnel Services)
Master of Education (Industrial Arts Education)
Master of Industrial Engineering
Master of Technology for International Development
Master of Life Sciences
Master of Landscape Architecture
Master of Applied Mathematics
Master of Mathematics
Master of Education (Mathematics Education)
Master of Mechanical Engineering
Master of Nutrition
Master of Product Design
Master of Public Affairs
Master of Recreation Resources
Master of Education (Science Education)
Master of Sociology
Master of Textile Technology
Master of Urban Design
Master of Education (Vocational Industrial Education)
Master of Wildlife Biology
Master of Wood and Paper Science

LANGUAGE REQUIREMENTS

The candidate for a master's degree in a designated field is exempt from the requirement of a reading knowledge of a modern foreign language.

THESIS REQUIREMENTS

In the School of Education the thesis requirement for the master's degree in each of the specialized fields may be waived by the department in which the degree is sought. When the thesis requirement is waived the student must complete the course "Introduction to Educational Research" or a departmental course in research, and a problem report.

OTHER REQUIREMENTS

Some of these master's programs have special requirements that differ from and sometimes exceed minimum requirements of Master of Arts or Master of Science degrees. Students are advised to obtain full particulars from the appropriate departments. In the main, however, requirements are the same as those for the Master of Arts and Master of Science degrees.

Master of Agriculture Degree and Master of Life Science Degree

The requirements for either of these degrees are as follows:

1. A total of 36 semester hours is required.
2. A minimum of four semester hours in special problems is required. Not more than six semester hours in special problems will be allowed. This work replaces the research thesis requirement for the Master of Science or Master of Arts degree.
3. There are no specific requirements as to courses in the 600 group.
4. A reading knowledge of a modern foreign language is not required.

In all other respects the requirements for the Master of Agriculture or the Master of Life Science degree are the same as those for the Master of Science degree.

Summary of Procedures for the Master's Degree in a Designated Field

1. Letter of inquiry from prospective student to Graduate School or depart ment head.
2. Mailing of proper forms to student by Graduate School.
3. Receipt of application forms and transcripts by Graduate School.
4. Application with transcript sent to department head for study.
5. Department head recommends acceptance of prospective student stating curriculum in which he will work and the degree sought.
6. Assuming the prospective student meets the minimum scholastic standards, notice of acceptance is mailed to him by the Graduate School. When the student's academic record fails to meet the minimum scholastic standards of the Graduate School, provisional admission may be granted upon sub mission by the student of evidence of a satisfactory performance on the Graduate Record Examination or National Teacher Examination. The National Teacher Examination is accepted only when approved by the department head and the graduate dean.
7. Permit to register is sent by the Graduate School to the registrar.
8. Student arrives, reports to the department head, is assigned an adviser and makes out a roster of courses in consultation with the departmental adviser.
9. Advisory committee of three or more faculty members, one of whom re-presents the minor field, appointed before the end of the first semester of

graduate study by the Graduate School after consultation with the department head. If departmental written examinations are required by the major department, there may be a minimum of two members on the advisory committee (one from the major field and one from the minor).

10. Plan of work prepared by the advisory committee and submitted in quadruplicate to the Graduate School by the end of the first semester in residence.
11. Plan of work approved by the graduate dean and three copies returned to the department head. One copy is kept in department files, one goes to the adviser and one is given to the student. Students preparing themselves for the professional degree in specialized fields of education should consult the chairmen of their committees with reference to their problem report.
12. Student applies for admission to candidacy for the master's degree. Application must be filed before the end of the first week of the last semester in residence.
13. Application is reviewed by the head of the major department and by the graduate dean and, if approved, the student becomes a candidate for the degree.
14. At the discretion of the advisory committee, written examinations in the major and/or minor fields may be required of the candidate. Written examinations, when required, normally should not be held earlier than the end of the first month of the last semester in residence and not later than one week before the oral examination.
15. Permission for the candidate to take the final oral examination is requested of the Graduate School at least two weeks before the examination.
16. Permission is granted by the graduate dean—date is set and examining committee appointed. The report on the final examination should be filed with the Graduate School as soon as the examination has been completed.
17. Graduate School certifies to the Registration Office and to the Administrative Board of the Graduate School that all requirements for the degree have been met and recommends the awarding of the degree.
18. All requirements must be completed within six calendar years.
19. Students must be registered in semester or session in which degree is to be awarded unless he has completed all requirements for the degree, including the passing of the final oral examination, by the first day of classes in the term in which the degree is to be awarded.

Summary of Procedures for the Master of Science Degree and the Master of Arts Degree

1. Letter of inquiry from prospective student to Graduate School or department head.
2. Mailing of proper forms to student by Graduate School.
3. Receipt of application form and transcript by Graduate School.
4. Application with transcript sent to department head for study.
5. Department head recommends acceptance of prospective student stating curriculum in which he will work and the degree sought.
6. Assuming the prospective student meets the minimum scholastic standards, notice of acceptance is mailed to him by the Graduate School. When the student's academic record fails to meet the minimum scholastic standards

of the Graduate School, provisional admission may be granted upon submission by the student of evidence of a satisfactory performance on the Graduate Record Examination or National Teacher Examination. The National Teacher Examination is accepted only when approved by the department head and the graduate dean.

7. Permit to register is sent by the Graduate School to the registrar.
8. Student arrives, reports to the department head, is assigned an adviser and makes out a roster of courses in consultation with department adviser.
9. Advisory committee of three or more faculty members, one of whom represents the minor field, appointed before the end of the first semester of graduate study by the Graduate School after consultation with the department head.
10. A thesis subject is selected and an outline of the proposed research submitted to the department head and to the student's advisory committee.
11. Plan of work prepared by the advisory committee in consultation with the student and submitted in quadruplicate to the Graduate School by the end of the first semester in residence.
12. Plan of work approved by the graduate dean and three copies returned to the department head. One copy is kept in department files, one goes to the adviser and one is given to the student.
13. Student passes language examination (if required by the major department). The language requirement must be satisfied before admission to candidacy can be granted.
14. Student applies for admission to candidacy for the master's degree. Application must be filed before the end of the first week of the last semester in residence and may not be filed before the language requirement is satisfied.
15. Application is reviewed by the head of the major department and by the graduate dean and, if approved, the student becomes a candidate for the degree.
16. At the discretion of the advisory committee, written examinations in the major and/or minor fields may be required of the candidate. Written examinations, when required, normally should not be held earlier than the end of the first month of the last semester in residence and not later than one week before the oral examination.
17. A copy of a preliminary draft of the thesis is submitted to the chairman of the student's committee for criticism.
18. At least two weeks prior to the final oral examination, the chairman of the student's advisory committee submits a corrected draft of the dissertation to members for review.
19. Permission for the candidate to take the final oral examination is requested of the Graduate School at least two weeks before the examination, and must be accompanied by a certification that the thesis is complete except for such revisions as may be necessary as a result of the final examination.
20. Permission is granted by the graduate dean—date is set and examining committee appointed. The report on the final examination should be filed with the Graduate School as soon as the examination has been completed.

21. Three copies of the thesis in final form approved by each member of the student's advisory committee and signed by the adviser must be submitted to the Graduate School at least four weeks before the end of the semester or summer session in which the degree is to be conferred.
22. Graduate School certifies to the Registration Office and to the general faculty that all requirements for the degree have been met and recommends the awarding of the degree.
23. All requirements must be completed within six calendar years.
24. Students must be registered in term in which degree is to be awarded unless he has completed all requirements for the degree, including submission of the thesis in final form to the Graduate School, by the first day of classes in the term in which the degree is to be awarded.

Doctor of Philosophy Degree

The degree of Doctor of Philosophy is offered by North Carolina State University in the following fields of study:

Animal Science
Applied Mathematics
Biochemistry
Biological and Agricultural Engineering
Biomathematics
Botany
Chemical Engineering
Chemistry
Civil Engineering
Crop Science
Economics
Electrical Engineering
Engineering Mechanics
Entomology
Fiber and Polymer Science
Food Science
Forestry
Genetics
Horticultural Science
Industrial Engineering
Marine Science
Materials Engineering
Mathematics
Mathematics and Science Education
Mechanical Engineering
Microbiology
Nuclear Engineering
Nutrition
Operations Research
Physics
Physiology
Plant Pathology
Psychology
Sociology
Soil Science
Statistics
Wood Science and Paper Technology
Zoology

The doctor's degree symbolizes the fact that the recipient is capable of undertaking original research and scholarly work at the highest levels without supervision. Therefore, the Doctor of Philosophy degree is not granted on the basis of successful completion of a given amount of course work, but rather upon the demonstration by a candidate of a comprehensive knowledge and high attainment in scholarship and research in a specialized field of study. These attainments are determined by the quality of the dissertation which the candidate prepares to report the results of original investigations and by passing successfully a series of rigorous and comprehensive examinations on the special and related fields of study.

COURSE OF STUDY

At the time of admission the student should, with the advice of the chairman of the department, elect a major field. During the student's first semester in residence, an advisory committee of at least four members will be appointed by the graduate dean, after consultation with the department head, to prepare with the student a plan of graduate work. Four copies of the program, signed by all members of the advisory committee and the department head or graduate administrator, are referred to the graduate dean for approval. When approved, three copies are returned to the department head, one being retained in the department files, a second copy is given to the chairman of the advisory committee and the third copy is given to the student. The subject of the dissertation must appear on the plan of work and any subsequent changes in the subject of the thesis or in the plan of graduate work must be reported to the Graduate school for approval.

There are no definite requirements in credit hours for the doctor's degree.

Major and Minor Fields: The Ph.D. degree is never granted for a program of miscellaneous studies. The program of work as a whole must be rationally unified and all constituent parts must contribute to an organized program of study and research. Courses must be selected from groups embracing one principal subject of concentration, called the major; and from cognate fields, called the minor. The minor program of study may be either a specific minor or interdisciplinary minor.

Specific Minor: Supplementary to his major study a candidate is required to offer a minor in a single discipline or field which, in the judgment of the student's advisory committee, provides relevant cognate support to the major field.

Interdisciplinary Minor: When an advisory committee finds that the needs of a doctoral student will be best served by preparation not available as a departmental minor, it has the alternative of developing a special program in lieu of the usual minor. To meet the requirements of this option a student may be required to complete courses in two or more departments outside his major, in related courses selected for their relevance to his particular area of con centration. Thus an appropriate program for a major in genetics might include courses in statistics, biochemistry and physiology. In the case of a split minor the two pertinent disciplines may be so identified on the "program of work" forms.

RESIDENCE

For the Doctor of Philosophy degree and the Doctor of Education degree, the student is expected to be registered for graduate work for at least six semesters beyond the bachelor's degree at some accredited graduate school. The amount of work from other institutions credited to the fulfillment of degree requirements will be determined by the dean after consultation with the student's advisory committee at the time the plan of graduate work is filed.

At least two residence credits, as defined below, must be secured in continuous residence (registration in consecutive semesters) as a graduate student at North Carolina State University. Failure to take work during the summer does not break the continuity; however, summer school work can be used to fulfill this requirement.

Residence credit is based on the number of credits of graduate work beyond the bachelor's degree carried in a given term. During a regular semester, residence credit is calculated in the following manner:

Semester Credits	*Residence Credits*
9 or more	1
6 8	⅔
less than six*	⅓

The residence credit for a six-week summer term is only one-half the corresponding amount for a regular semester; i.e., six semester hours carry one-third residence credit and less than six credits, one sixth residence credit.

The candidate must complete all requirements for the degree, including the final examination on his dissertation and submission of the dissertation in final form to the Graduate School, within a period of seven calendar years from the date of admission to candidacy for the degree.

LANGUAGES

A reading knowledge of scientific literature in at least one modern foreign language is required by most departments for the Doctor of Philosophy degree.* The programs in biomathematics, chemistry, entomology, statistics and mathematics require a reading knowledge of two foreign languages or a comprehension in depth of one language. For the Doctor of Education degree the decision as to whether or not there will be a requirement is left with the student's advisory committee.

Comprehension in depth is to be interpreted as a proven ability in the oral and composition elements of a particular language as well as the reading knowledge normally required. Ph.D. students desiring to offer one language in depth should consult with the head of the Department of Modern Languages as to the specific courses to be followed to achieve this comprehension. Specific arrangements may differ, depending upon the student's previous background in the language. It is emphasized that students choosing to achieve competence in depth in one language will generally find this alternative more rigorous than proof of reading ability in two languages.

If the student elects to work in two languages, the languages may be a combination of Romance and Slavic, Romance and Germanic, or Slavic and Germanic.

Students whose native tongue is some language other than English may use English as one of the two languages when two are required for the Doctor of Philosophy degree. When English is submitted in partial fulfillment of the language requirements, the native language may not be used to satisfy one of the language requirements.

When only one language is required in a student's program, certification for that language must occur on this campus.

THE DISSERTATION

The doctoral dissertation presents the results of the candidate's original investigations in the field of his major interest. It must represent a contribution to knowledge, adequately supported by data and written in a manner consistent

* Including registration for thesis preparation on campus.
* The foreign language requirements for particular degree programs may be modified subsequent to the publication of this catalog. A student would be well advised to check with the department in which he hopes to be working toward an advanced degree.

with high standards of excellence in scholarship. Detailed instructions relating to the thesis may be obtained from the Graduate Office.

Publication of the results obtained in the thesis investigation is expected. Each copy of the thesis must be accompanied by an abstract of approximately 500 words.

The dissertation will be examined by all members of the examining committee and must receive their approval to be acceptable to the Graduate Office.

Two copies of the dissertation in final form, signed by all members of the student's advisory committee, and five copies of the abstract must be presented to the Graduate School not later than four weeks before the date on which the degree is to be awarded.

North Carolina State now has an agreement with University Microfilms, Inc., of Ann Arbor, Michigan, by which all doctoral dissertations are microfilmed and abstracts of the dissertations are published in "Dissertation Abstracts."

EXAMINATIONS

Not earlier than the end of the second year of graduate study and not later than one semester (or its equivalent) before the final orals can be scheduled, each doctoral student is required to pass general comprehensive examinations (known as the qualifying or preliminary examinations). The examinations are given by an examining committee of graduate faculty members appointed by the graduate dean after consultation with the head of the department in which the student's major work has been taken. The examining committee usually consists of the student's advisory committee and a representative of the Graduate School, but may include other members of the graduate faculty. The examinations are open to all members of the graduate faculty who may care to attend.

Authorization for the qualifying examination is requested of the Graduate School by the chairman of the student's advisory committee when the major part of the student's program of course work has been completed and when, in the judgment of the committee, the student is prepared to devote the greater part of his time to the prosecution of his research study. Members of the examining committee will be notified of their appointment by the Graduate Office. Official printed forms will be supplied to the chairman of the examining committee for a report of the results of the examination.

The examination consists of two parts written examinations and an oral examination held before the entire examining committee. When, in the judgment of the chairman of the student's advisory committee, the student is ready for the written examinations, arrangements may be made. Two approaches are acceptable. In the first, the chairman requests examination questions from each member of the examining committee. Each set of questions is given to the student by the chairman in any order that may seem appropriate. The questions, together with the student's answers, are then returned to the members of the committee for grading. This procedure is still used by departments having a relatively small number of doctoral candidates. Many of the larger departments, however, have found it impractical to have separate written examinations prepared by each student's committee and have instituted departmental written examinations to be used for all candidates. These examinations are given several times during the year and scheduled dates are announced well in advance. Where written departmental examinations of this kind are made available, the student majoring or minoring in the field of the department will be expected to make arrangements for taking these examinations. Questions on written examinations may cover any phase of the course work taken by the student during the period of his graduate study or any subject logically related and basic to an understanding of the sub-

ject matter of the major and minor areas of study. They should be designed to measure the student's mastery of these subject matter fields and the adequacy of his preparation for research investigations.

Upon satisfactory completion of the written examinations the student must pass an oral examination before the entire examining committee. This examination is usually held within two weeks after the chairman of the examining committee has certified to the Graduate School that the student has completed satisfactorily the written examinations. The members of the examining committee will be notified by the Graduate School of the time and place arranged for the oral examination. The oral examination is designed to test the student's ability to relate factual knowledge to specific circumstances. In the oral examination the student is expected to use his knowledge with accuracy and promptness and to demonstrate that his thinking is not limited to the facts learned in course work.

A unanimous vote of approval is required for passing the preliminary examination. Approval may be conditioned, however, upon the completion of additional work in some particular field to the satisfaction of the committee. In case a single dissenting vote is cast, the course of action to be taken will become a matter for decision by the Administrative Board. Upon receiving the approval of the examining committee the student is admitted to candidacy for the doctorate.

A final oral examination is also required. An interval of at least one semester or its equivalent must elapse between admission to candidacy and the final oral examination.

This examination is held after the dissertation has been completed and consists of a defense by the candidate of the methods used and the conclusions reached in his research study. The examination is conducted by an examining committee. The examining committee usually includes the student's advisory committee, plus a representative of the Graduate School, although this procedure is not always adopted. The examining committee is appointed by the graduate dean after consultation with the head of the student's major department.

Failure of a student to pass either the preliminary or the final examination terminates his graduate work at this institution unless otherwise recommended by the examining committee. No reexamination may be given until at least one full semester has elapsed since the first examination. Only one reexamination is permitted.

See Summary of Procedures for Doctor of Philosophy and Doctor of Education Degrees below.

ADMISSION TO CANDIDACY

A student is admitted to candidacy after he has successfully passed the preliminary examinations. The language requirements must be fulfilled before permission to take the preliminary examination is granted.

Doctor of Education Degree

The School of Education offers graduate programs leading to the Ed.D. degree for majors in adult education and occupational education. Details are presented on page 126. The philosophy and requirements for the Ed.D. degree are the same as those expressed herein for the Doctor of Philosophy degree.

ADDITIONAL INFORMATION

A booklet containing detailed instructions about the form of the dissertation may be obtained from the Graduate School.

Further information concerning graduate work at North Carolina State University may be secured from Dr. Walter J. Peterson, Dean of the Graduate School, North Carolina State University, Raleigh, North Carolina 27607.

Summary of Procedures for the Doctor of Philosophy and Doctor of Education Degrees

1. Letter of inquiry from prospective student to Graduate School or department head.
2. Mailing of proper forms to student by Graduate School.
3. Receipt of application forms by Graduate School.
4. Application with transcript sent to department head for study.
5. Department head recommends acceptance of prospective student stating curriculum in which he will work.
6. Assuming the prospective student meets the minimum scholastic standards, notice of acceptance is mailed to him by the Graduate School.
7. Permit to register is sent by Graduate School to the registrar.
8. Student arrives, reports to the department head, is assigned an adviser and makes out a roster of courses in consultation with departmental adviser.
9. Advisory committee of at least four members is appointed in the first term of graduate study by the graduate dean after consultation with the department head.
10. Plan of work is prepared by the advisory committee in consultation with the student and submitted in quadruplicate to the Graduate School by the end of the first semester in residence.
11. Plan of work is approved by the graduate dean and three copies returned to the department head. One copy is kept in department files, one goes to the adviser and one is given to the student.
12. A dissertation subject is selected and an outline of the proposed research submitted to the department head and the student's advisory committee.
13. Student passes language examination(s) (See page 54.)
14. When the student has completed satisfactorily all the courses in the minor field on his plan of work, he may, with the consent of the chairman of his committee, take the written qualifying examination in the field of his minor. If desirable, this examination may be taken if all but one of the courses in the minor field have been completed and the student is taking the last such course during the semester in which the examination is held. The results of this examination will be reported to the Graduate School. The examination in the minor field may be combined with the examination in the major field.
15. The written examination in the major field may be scheduled upon approval of the dean of the Graduate School not earlier than the end of the second year of graduate study and not later than one semester before the final oral examination would be scheduled. The results of this examination will be reported to the Graduate School.
16. When all written examinations have been completed satisfactorily, the oral qualifying examination may be held. The Graduate School is notified two

weeks in advance of the time and place of this examination. The report of the examination is sent to the Graduate School. If the report is favorable, the student is admitted to candidacy.

17. A copy of the preliminary draft of the dissertation is submitted to the chairman of the student's committee for criticism.

18. At least two weeks prior to the final oral examination, the chairman of the student's advisory committee submits a corrected draft of the dissertation to members for review.

19. One semester after admission to candidacy or later, permission for the candidate to take the final oral examination is requested of the Graduate School by the chairman of the candidate's advisory committee. Requests should be filed at least two weeks before the date of the examination and must be accompanied by a certification that the thesis is complete except for such revisions as may be necessary as a result of the final examination.

20. Permission is granted by the graduate dean if the student's record is in order. A date is set and examining committee appointed. The report on the examination should be filed with the Graduate School as soon as the examination has been completed.

21. Two copies of the thesis in final form and five copies of the abstract must be submitted to the Graduate School not later than four weeks before the date on which the degree is to be awarded. It must carry the signatures of all members of the advisory committee.

22. The Graduate School certifies to the Registration Office and to the general faculty that all requirements for the degree have been met and recommends the awarding of the degree.

23. All requirements must be completed within seven calendar years from date of admission to candidacy for the doctoral degree.

24. The student must be registered in the term in which the degree is to be awarded unless he has completed all requirements for the degree, including submission of the thesis in final form to the Graduate School, by the first day of classes in the term in which the degree is to be awarded.

FIELDS OF INSTRUCTION

The course descriptions are planned for the academic years 1972 73 and 1973-74, unless indicated otherwise. Specific courses may not be offered, however, if regis tration for a course is too low, or if faculty or facilities are not available.

Courses in the 500 series are open to seniors and graduate students. All courses in this series carry full graduate credit. Courses in the 600 series are open to graduate students only. Master's programs must include not less than 20 semester hours from courses in the 500 and 600 series.

In a typical course description, the semester hours of credit, the number of actual lecture and laboratory hours of meeting per week, and the term or terms in which the course is offered are shown in this manner: 2(1-2) FS Sum. or 1-3 FS Sum.

The 2 indicates the number of semester hours credit given for satisfactory completion of the course. The (1-2) indicates that the course meets for one hour of lecture and for two hours of laboratory work each week. The 1-3 indicates that a maximum of three and a minimum of one semester hours credit can be earned. This is to be arranged with the instructor. The F designates that the course is to be given in the fall semester. Likewise, the S designates spring and the Sum., summer.

Adult and Community College Education

GRADUATE FACULTY

Professor EDGAR J. BOONE, *Head*

Professors: ROBERT J. DOLAN, CURTIS TRENT; *Extension Professor:* JAMES D GEORGE; *Visiting Professor:* ISAAC E. READY; *Adjunct Professors:* BEN E. FOUNTAIN, EMILY H. QUINN; *Associate Professors:* WILLIAM L. CARPENTER, WILLIAM L. GRAGG; *Assistant Professors:* J. CONRAD GLASS, JR., DAN B. LUMSDEN, GERALD E. PARSONS, GEORGE D. RUSSELL, RONALD W. SHEARON; *Adjunct Assistant Professor:* CHARLES J. LAW, JR.

The Department of Adult and Community College Education is a component of both the School of Education and the School of Agriculture and Life Sciences. It offers programs of study leading to the Master of Education, Master of Science and Doctor of Education degrees with a major in adult and community college education. The publics toward whom the program is directed include administrators, supervisors and teachers in university and cooperative extension and com munity colleges.

The curriculum of the Department of Adult and Community College Education is interdisciplinary. It is specifically designed to help students acquire an integrated conceptual and theoretical framework derived from the behavioral sciences, social sciences and education that will equip them to plan, administer and effect viable and relevant programs of change with individual learners, groups and larger societal aggregates in both formal and informal settings.

Further, the curriculum provides opportunities for students to acquire a high level of competance in identifying and diagnosing problematic situations and proposing alternative courses of action and strategies in seeking solutions to problems.

Cognate fields of study include sociology, anthropology, psychology, politics and economics.

The Department of Adult and Community College Education is housed in Ricks Hall and Poe Hall, which are centrally located in respect to all other ele ments on the University campus. Graduate students on assistantships and internships are provided with office space and equipment. Other graduate students in the program are provided study space when possible. The department has a well equipped library which includes major professional journals in the behavioral sciences, social sciences and education.

Facilities are ideal for students whose research problems may involve the extensive analysis of data. An IBM-360/75 System is available at the Triangle Universities Computation Center (TUCC); and IBM 360/40, IBM-1130 and IBM-1050 terminals are in operation on the North Carolina State University campus.

FOR GRADUATES AND ADVANCED UNDERGRADUATES

ED 501 (SOC 501) LEADERSHIP 3(3-0) FS Sum.
(See sociology, page 289.)

ED 502 (PS 502) PUBLIC ADMINISTRATION 3(3-0) FS Sum.
(See politics, page 266.)

ED 503 THE PROGRAMMING PROCESS IN ADULT EDUCATION 3(3-0) S Sum.
Prerequisites: ED 501, consent of instructor

The principles and processes involved in programming, including basic theories and concepts supporting the programming process. Attention will be given to the general framework in which programming is done, the organization needed, and the program roles of both professional and lay leaders. Graduate Staff

ED 510 ADULT EDUCATION: HISTORY, PHILOSOPHY, CONTEMPORARY NATURE 3(3-0) FS Sum.
Prerequisite: Graduate standing

A study of the historical and philosophical foundations of adult education from ancient times to the present, giving attention to key figures, issues, institutions, movements and programs, including consideration of the relationship between adult education's historical development and prevailing intellectual, social, economic and political conditions. Consideration of adult education's contemporary nature, present day schools of thought on its objectives, and trends.

Graduate Staff

ED 513 (SOC 513) COMMUNITY ORGANIZATION 3(3-0) F
(See sociology, page 290.)

ED 559 PRINCIPLES OF ADULT EDUCATION 3(3 0) F Sum.
Prerequisite: Six hours in education

Principles involved in adult education programs including theories and concepts undergirding and requisite to these programs. Emphasis will be given to the interrelationship of the nature of adult learning, the nature of the subject matter and setting in which learning occurs. The applicability of relevant principles and pertinent research findings to adult learning will be thoroughly treated.

Graduate Staff

ED 596 TOPICAL PROBLEMS IN ADULT EDUCATION Credits Arranged
Prerequisite: Graduate standing

Study and scientific analysis of problems in adult education, and preparation of a scholarly research type of paper. Graduate Staff

FOR GRADUATES ONLY

ED 600 THEORY OF ORGANIZATION AND ADMINISTRATION IN ADULT EDUCATION I 3(3 0) F Sum.
Prerequisites: ED 503, PS 502 (ED 502), SOC 541

Theory of organization relating to adult education social systems as a basis for understanding administrative behavior. An in-depth analysis of the structure, function and process of adult education social systems patterns of organizational growth and change, behavior patterns of functionaries, and reciprocal influence of the adult education system and other social systems in the society.
Graduate Staff

ED 601 THEORY OF ORGANIZATION AND ADMINISTRATION IN ADULT EDUCATION II 3(3 0) Sum.
Prerequisite: ED 600 or a comparable course(s) on organizational theory

Philosophy of administration as a basis for administering an adult education institution. Theory relevant to administration of such an organization. Principles of administration as they relate to planning, organizing, staffing, initiating, delegating, integrating, motivating, decision-making, communicating, establishing standards, financing and budget defense and control, and measuring results. Administrative behavior of the adult education executive. Graduate Staff

ED 696 SEMINAR IN ADULT EDUCATION 1(1-0) S
Prerequisite: Graduate standing

Identification and scientific analysis of major issues and problems relevant to adult education. Credit for this course will involve the active participation of the student in a formal seminar and the scientific appraisal and solution of a selected problem. The course is designed to help the student acquire a broad perspective of issues confronting adult educators and to acquire experiences in the scientific analysis and solution of specific issues. Graduate Staff

Agricultural Education

GRADUATE FACULTY

Professor C. CAYCE SCARBOROUGH, *Head*
Professors: JOHN K. COSTER, J. BRYANT KIRKLAND; *Associate Professors:* TEXTON R. MILLER, *Graduate Administrator; Research Associate Professor:* CHARLES H. ROGERS; *Assistant Professor:* CHARLES D. BRYANT; *Adjunct Assistant Professor:* WILLIAM J. BROWN, JR.

The Department of Agricultural Education offers programs of study leading to the Master of Science, the Master of Education and the Doctor of Education degrees. Graduate programs are designed to meet the needs of individual students for further study and research as well as to prepare for educational leadership roles in teaching, administration, supervision and research.

In addition to the many resources available to all North Carolina State graduate students, agricultural education students have an additional resource available in administrative and consultant staff members of the State Department of Public Instruction and the Department of Community Colleges in Raleigh.

Graduate assistantships are available. A concerted effort is made to insure that the assistantship experiences are related to the career plans of individual students.

FOR GRADUATES AND ADVANCED UNDERGRADUATES

ED 554 Planning Programs in Agricultural Education 3(3-0) FS
Prerequisite: ED 411 or equivalent

Analysis of theory of planning and change. Consideration of the need for planning programs in agricultural education; objectives and evaluation of community programs; use of advisory groups; organization and use of facilities; role of the leader. Mr. Bryant

ED 565 Agricultural Occupations 3(3-0) F
Prerequisite: ED 411

Theory of education for work and relationship to agricultural occupations. Career development in agricultural occupations. Curriculum development for teaching agricultural occupations. Mr. Scarborough

ED 566 Occupational Experience in Agriculture 3(3-0) S
Prerequisite: ED 411

Theoretical foundations of occupational experience in educational programs. Modern concepts of experiential programs. Principles of program design and development. Evaluation of work experience in agriculture. Mr. Miller

ED 568 Adult Education in Agriculture 3(3-0) F
Prerequisite: ED 411 or equivalent

Designed to meet the needs of leaders in adult education. Opportunity to study some of the basic problems and values in working with adult groups. Particular attention will be given to the leadership role in educational programs for adults.
Mr. Scarborough

ED 593 Special Problems in Agricultural Education
Credits Arranged FS Sum.
Prerequisite: ED 411 or equivalent

Opportunities for students to study current problems under the guidance of the staff. Graduate Staff

ED 597 Special Problems in Education 1-3 FS
Prerequisite: Graduate standing and permission of instructor

The major purpose of this course is to help teachers and others involved in occupational exploration programs to further develop their understandings and competencies in these areas. The approach will be based upon an understanding of the philosophy underlying the world of work and the role of occupational exploration in educational programs for young people. Messrs. Scarborough, Bryant

FOR GRADUATES ONLY

ED 617 PHILOSOPHY OF AGRICULTURAL EDUCATION 3(3-0) S
Prerequisite: ED 554 or equivalent

An examination of educational philosophies and their relation to current educational programs in agricultural education. Mr. Scarborough

ED 664 SUPERVISION IN AGRICULTURAL EDUCATION 3(3-0) FS Sum.
Prerequisite: ED 563 or equivalent

Organization, administration, evaluation and possible improvement of supervisory practice; theory, principles and techniques of effective supervision in agricultural education at different levels. Mr. Scarborough

ED 688 RESEARCH APPLICATION IN OCCUPATIONAL EDUCATION 3(3 0) FS Sum.
Prerequisite: ED 615

This course will be concerned with methodology, application, analysis and synthesis of research in occupational education. A review of current occupational education studies, clustered by areas, will be made with attention to statistical techniques, data collecting, data handling and the audience and impact of particular projects and research organizations. The class activities in research application are designed to bridge the gap between the theories of research methodology and the student's independent research projects. Graduate Staff

ED 689 EVALUATION IN OCCUPATIONAL EDUCATION 3(3 0) FS Sum.
Prerequisites: ED 615, ST 513

This course will be concerned with the conceptual and methodological aspects of occupational education evaluation, with attention to techniques for determining empirically the extent to which educational goals are being achieved, to locate the barriers to the advancement of these goals and to discover the consequences of educational programs. Graduate Staff

ED 693 ADVANCED PROBLEMS IN AGRICULTURAL EDUCATION Credits Arranged FS Sum.
Prerequisite: ED 554 or equivalent

Study of current and advanced problems in the teaching and administration of educational programs, evaluation of procedures and consideration for improving. Graduate Staff

ED 694 SEMINAR IN AGRICULTURAL EDUCATION Maximum 2 1(1-0) FS Sum.

A critical review of current problems, articles, and books of interest to students of agricultural education. Graduate Staff

Air Conservation

(An interdepartmental, intercampus graduate program.)

An air conservation faculty of some 50 persons represents 20 departments in four schools. A current listing is available on request to the Graduate School.

The need to conserve air resources follows from its finiteness as opposed to the logarithmically increasing world population and the more than proportional emission of wastes into it. Excess deaths occurring in occasional air-pollution

"episodes", the increased incidence of respiratory problems, instances of widespread crop damage and loss of visibility are other indices of the growing seriousness of the problem. Recognizing the need for multi-disciplinary study of this pressing societal problem, the Graduate School has approved a minor program in Air Conservation.

A graduate student desiring to minor in Air Conservation will have on his committee a member of the graduate faculty, from outside his major department, representing this minor field. While there are no restrictions on the major, students minoring in Air Conservation should have a strong background in the life sciences, the physical sciences or engineering. The minor program will normally consist of 10 or more credits for the master's degree, 16 or more for the doctorate.

A variety of courses bearing on different aspects of the air-conservation problem may be taken on this campus (under the auspices of the Triangle Universities Consortium on Air Pollution) or at Chapel Hill or Duke. The listing below shows courses available after 1971.

Air Pollutants and Their Sources

CH	695	SPECIAL TOPICS IN CHEMISTRY
TC	401	SOURCES AND CONTROL OF POLLUTION FROM THE TEXTILE INDUSTRY
*ENVR	243	AIR AND ITS CONTAMINANTS
*ENVR	247	CHEMISTRY OF THE TROPOSPHERE

Meteorology and Pollutant Transport

MY	555	METEOROLOGY OF THE BIOSPHERE
MY	556	AIR POLLUTION METEOROLOGY
*ENVR	241	MECHANICS OF AEROSOLS

Air Sampling and Analysis

ST	511	EXPERIMENTAL STATISTICS FOR BIOLOGICAL SCIENCES, I
*ENVR	144	AIR POLLUTION MEASURING, MONITORING, AND SURVEY
*ENVR	221	INSTRUMENTAL METHODS OF ANALYSIS

Effects on Human and Animal Receptors

BO(ZO)	360	INTRODUCTION TO ECOLOGY
*ENVR	143	APPLIED PHYSIOLOGY AND TOXICOLOGY
*ENVR	246	BIOLOGICAL EFFECTS OF AIR POLLUTION

Effects on Plant Receptors

BO(ZO)	360	INTRODUCTION TO ECOLOGY
BO	421	PLANT PHYSIOLOGY
*ENVR	246	BIOLOGICAL EFFECTS OF AIR POLLUTION

Air-Quality Management

CE	472	ELEMENTS OF AIR QUALITY MANAGEMENT
CHE	535	ENGINEERING ECONOMY IN AIR-POLLUTION CONTROL SYSTEMS
MAE	409	PARTICULATE CONTROL IN INDUSTRIAL ATMOSPHERIC POLLUTION
MAE	510	THEORY OF PARTICULATE COLLECTION IN AIR POLLUTION CONTROL
WPS	525	POLLUTION ABATEMENT IN FOREST PRODUCTS INDUSTRIES
*ENVR	245	AIR POLLUTION CONTROL

* Courses offered at UNC-CH or at Duke.

Air-Quality Law and Institutions

PS	502	PUBLIC ADMINISTRATION
*ENVR	217	SYSTEMS ANALYSIS IN ENVIRONMENTAL PLANNING
*HADM	102	LEGAL BASIS OF PUBLIC HEALTH PRACTICE
*PLAN	233	NATURAL RESOURCES LAW AND POLICY
*DUKE		NATURAL RESOURCES LAW
*DUKE		SEMINAR IN AIR POLLUTION

Air-Conservation Economics

EC	401	ECONOMIC ANALYSIS FOR NON-MAJORS
EC	515	WATER RESOURCES ECONOMICS
EC	550	MATHEMATICAL MODELS IN ECONOMICS
OR	501	INTRODUCTION TO OPERATIONS RESEARCH

Animal Science

GRADUATE FACULTY

Professor IRA D. PORTERFIELD, *Head*

Professors: ELLIOTT R. BARRICK, EDWARD G. BATTE, ALBERT J. CLAWSON, LEMUEL GOODE, GEORGE HYATT, JR., JAMES M. LEATHERWOOD, JAMES G. LECCE, JAMES E. LEGATES, *Dean, School of Agriculture and Life Sciences,* HAROLD A. RAMSEY, HOWARD A. SCHNEIDER; FRANK H. SMITH, LESTER C. ULBERG, GEORGE H. WISE; *Professor Emeritus:* HAMILTON A. STEWART; *Extension Professor:* ROBERT F. BEHLOW; *Associate Professors:* EDWARD V. CARUOLO, DONALD G. DAVENPORT, EMMETT U. DILLARD, EUGENE J. EISEN, RAYMOND W. HARVEY, EVAN E. JONES, JOHN J. MCNEILL, RICHARD D. MOCHRIE, DANIEL J. MONCOL, RICHARD M. MYERS, ALLEN H. RAKES, ODIS W. ROBISON, JOHN C. WILK; *Extension Associate Professors:* JAMES R. JONES, FRANK D. SARGENT; *Assistant Professors:* BRYAN H. JOHNSON, WILLIAM L. JOHNSON

ASSOCIATE MEMBERS OF THE DEPARTMENT

Professors: CHARLES H. HILL, SAMUEL B. TOVE; *Associate Professor:* HARVEY J. GOLD

The Department of Animal Science offers programs leading to the degrees of Master of Science and Doctor of Philosophy with majors in six different disciplines. Animal science traditionally has been oriented toward the study of domestic animals. Although the problems of the livestock industry have not all been solved, the overall approach to research in the general area of animal science has changed and will continue to change in the future. In order to obtain added insight into the underlying problems currently facing animal science, students are trained in those disciplines which provide a basic understanding of the processes of life.

The Department of Animal Science offers a unique opportunity for students to obtain advanced training in a diversity of basic sciences and to integrate this experience into the framework of a living system. Students in this department may obtain degrees in the disciplines of biochemistry, genetics, microbiology, nutrition and physiology as well as a major in animal science. Students with a major in animal science specialize in one or more of the basic biological disciplines

* Courses offered at UNC CH or at Duke.

or in the more applied areas such as economics and management. This major also provides for the student who desires to achieve a multi-disciplinary experience. Students who desire a major in one of the disciplines develop a program extremely strong in the basic sciences. At the successful termination of such a program they are qualified to compete with students trained in that discipline, but also have the added capabilities of integrating basic knowledge into a complete living system; i.e., the domestic animal. The student may minor in any one of the above areas or may choose as his minor such areas as statistics, economics, chemistry or other biological sciences. His research experiences can be with a specific species or with a variety of species from cattle to mice.

The availability of a variety of modern laboratories, specialized equipment and many different species which serve as biological models enables the student to become familiar with research tools and their use in expanding knowledge in the several segments which go to make up the field of animal science. The required list of courses and the research program is developed for the individual student. The objective of the program is to provide the student with a challenging program offering him an opportunity to develop his creative ability to such an extent that he will have the knowledge and motivation to contribute significantly to his chosen discipline.

FOR ADVANCED UNDERGRADUATES

ANS 401 REPRODUCTIVE PHYSIOLOGY 3(2-3) S
Prerequisite: ZO 421

Current concepts of physiology as related to mammalian reproduction. Emphasis is placed upon understanding physiological processes, how they are influenced by external forces and their importance in reproductive performance. The student may be required to select, design and conduct a special research project.

ANS 402 BEEF CATTLE MANAGEMENT 3(2-3) S
Prerequisite: ANS 204

A study of modern principles and practices in beef cattle care and management. Special emphasis is placed upon the application of the principles of genetics, ruminant nutrition and animal health to cow-calf programs and to stocker and feeder cattle operations.

ANS 403 SWINE MANAGEMENT 3(2-3) S
Prerequisite: ANS 204

A study of the economic, nutritional, genetic, physiological and managerial factors affecting the operation of modern swine enterprises.

ANS 404 DAIRY CATTLE MANAGEMENT 3(2-3) S
Prerequisite: ANS 204

A study of practical dairy farm management, including feed acquisition and utilization, breeding and selection, health and sanitation, herd replacements and dairy farm buildings. Particular emphasis is placed upon the consequences of management alternatives and the importance of herd and farm business records. (Offered spring 1972 and alternate years.)

ANS 405 LACTATION 3(2-3) F
Prerequisite: ZO 421

Gross and microscopic anatomy of the developing and the mature mammary gland. Physiological processes involved in milk secretion and removal of milk from the gland. A special research project is required.

ANS 406 SHEEP MANAGEMENT 3(2-3) F
Prerequisite: ANS 204

A study of the economic, genetic, nutritional, physiological and managerial factors affecting the operation of the modern sheep enterprise.

ANS 409 (FS 409) MEAT AND MEAT PRODUCTS 3(2 3) S
(See food science, page 158.)

ANS 410 HORSE MANAGEMENT 3(2-2) F

Application of fundamentals of selection, nutrition, breeding and animal health to light horses. Managerial details of horse care are covered.

ANS 411 BREEDING AND IMPROVEMENT OF DOMESTIC ANIMALS 3(2-2) F
Prerequisite: GN 411

Genetic principles are stressed in relation to the improvement of economically important domestic species. Emphasis will be given to breeding plans and specific requirements for individual species.

ANS 415 (PO 415, NTR 415) COMPARATIVE NUTRITION 3(3-0) F
Prerequisite: CH 220 or CH 221

Fundamentals of animal nutrition, including classification of nutrients, their requirement and general metabolism by different species for health, maintenance, growth and other productive functions.

ANS 490 ANIMAL SCIENCE SEMINAR 1(1-0) S

Review and discussion of special topics and the current literature pertaining to all phases of animal science.

FOR GRADUATES AND ADVANCED UNDERGRADUATES

ANS 502 (PHY 502) REPRODUCTIVE PHYSIOLOGY OF VERTEBRATES 3(3-0) S
Prerequisite: ZO 421 or consent of instructor

Emphasis will be placed on discussions of mechanisms which control the reproductive processes. Mechanisms which are species limited will be compared with those which are shared by all species. Current knowledge of some subsystems will be investigated in detail while others will be referred to in reviews of well-documented research findings. Mr. Ulberg

ANS 505 DISEASES OF FARM ANIMALS 3(3-0) F
Prerequisites: CH 101, CH 103

The pathology of bacterial, viral, parasitic, nutritional, thermal and mechanical disease processes. Mr. Batte

ANS 508 (GN 508) GENETICS OF ANIMAL IMPROVEMENT 3(3-0) S
Prerequisites: GN 411, ST 511

Emphasis is placed on the utilization of basic principles of population and quantitative genetics in animal improvement. Factors affecting genic and genotypic frequencies and methods of estimating genetic and nongenetic variance, heritabilities and breeding values are presented. The roles of mating systems and selection procedures in producing superior genetic populations are examined.

ANS 590 TOPICAL PROBLEMS IN ANIMAL SCIENCE Maximum 6 FS

Special problems may be selected or assigned in various phases of animal science. Graduate Staff

FOR GRADUATES ONLY

ANS 603 (GN 603) POPULATION GENETICS IN ANIMAL IMPROVEMENT 3(3-0) F
Prerequisites: ST 512, GN 506

A study of the forces influencing gene frequencies, inbreeding and its effects, and alternative breeding plans.

ANS 604 (PHY 604) EXPERIMENTAL ANIMAL PHYSIOLOGY 4(2-4) F
Prerequisite: ZO 513 (PHY 513) or equivalent

A study of the theories and techniques involved in the use of animals in physiological investigation. Messrs. Caruolo, Wise

ANS 622 (ST 622) PRINCIPLES OF BIOLOGICAL ASSAYS 3(3-0) S
Prerequisites: BCH 551, ST 512

Techniques and designs of biological assays. The interrelationship of logical principles, designs and analyses is emphasized. Graduate Staff

ANS 653 (BCH 653) MINERAL METABOLISM 3(3-0) F
(See biochemistry, page 74.)

ANS 690 SEMINAR IN ANIMAL NUTRITION 1(1-0) FS
Prerequisite: Consent of seminar leaders

Orientation in philosophy of research, preparation for research and general research methodology. Graduate Staff

ANS 699 RESEARCH IN ANIMAL SCIENCE Credits Arranged

A maximum of six hours is allowed toward the master's degree; no limitation on credits in doctorate program. Graduate Staff

Architecture

GRADUATE FACULTY

Professor ROBERT P. BURNS, JR., *Head*
Professors: JOSEPH H. COX, HARWELL H. HARRIS, HENRY L. KAMPHOEFNER, *Dean, School of Design*, DUNCAN R. STUART; *Associate Professors:* PETER BATCHELOR, GEORGE L. BIRELINE, JOHN P. REUER, HENRY SANOFF, VERNON F. SHOGREN; *Assistant Professor:* ROGER H. CLARK

The Department of Architecture offers programs of study leading to the Master of Architecture degree. While designed primarily as the concluding two-year professional component to follow the new four-year undergraduate Bachelor of Environmental Design curriculum in the total six-year program, the graduate program also provides courses of study for graduates holding the five-year Bachelor of Architecture degree. In addition, applicants with undergraduate degrees in fields other than architecture may be accepted as graduate students, and somewhat extended programs of study leading to the Master of Architecture degree will be designed to build on their previous academic experience. A core of new introductory advanced design courses (DN 505 Introduction to Design as Task, DN 506 Introduction to Design as Technique, and DN 507 Introduction to Design as Practice) has been developed to provide an intensive orientation to

current concepts and activities in the environmental design field for entering graduate students who come from non-design backgrounds.

A parallel two year graduate program in urban design leading to the Master of Urban Design degree is also offered by the Department of Architecture. With the initiation of this new program and with the existing graduate programs in architecture, landscape architecture and product design, the School of Design offers the most comprehensive and innovative environmental design education program in the southeast United States. (For detailed information on the graduate program in urban design see page 318.)

The nature and complexity of the tasks which confront the architect make it paramount that the master's program be broadly based and diversified. Reasonable flexibility is provided to structure each student's program of study in accordance with expressed interests and demonstrated capabilities. Essentially, master's candidates are afforded concentrated education in depth so that they can prepare themselves for significant professional involvement in the environmental design field as practitioners, teachers, researchers or in other more specialized areas.

A thorough mastery of this broad field requires that a graduate student attain a basic understanding of design methodology, the relevant technologies, the cultural and economic factors in design as well as ethical and operational aspects of architectural practice. While a clear comprehension of these subjects is essential, the architect must also understand their interrelationships and must demonstrate competence in their application through physical design activity.

Design studio concentration in the advanced classes vary somewhat from year to year depending on faculty expertise and student interest. The Department of Architecture identifies with the immediate and long-range needs of the community, state and region and sees the advanced design studio as offering an appropriate opportunity for addressing society's most critical environmental conditions. In recent semesters advanced studio options have included industrialized housing; urban renewal and new towns design; programming, planning and design of educational and health care delivery systems and facilities; urban systems analysis and design.

The program requires of all students undertaking the normal two-year master's program a minimum of 48 credit hours of course work of which 75 percent will be in the major field; the remainder, constituting the minor, will be elected from various specialized areas. Course work in the minor field will be selected to reinforce the student's individual abilities and long-range career goals. While it is conceivable that almost any relevant field of study could be explored, it is assumed that the following interdisciplinary areas of investigation would most frequently be chosen: construction management; environmental policy planning; housing systems; environmental psychology; human behavior; urban physical systems; urban technology; facilities planning—educational, health care, etc.; environmental technology; design theory and philosophy; and visual communication.

A terminal project, constituting the final test of the candidate's mastery of his graduate program, may be written or drawn and shall consist of an interdis ciplinary investigation of an approved problem which relates architectural studies to the student's minor field. For graduates holding the Bachelor of Archi tecture degree, a minimum program of 30 credit hours is required.

Departmental resources, including both physical facilities and faculty, are of exceptional quality. Members of the graduate faculty have been widely recognized for the excellence of their educational and professional accomplishments. A number of the faculty are active in independent consultation and private

architectural practice and have received numerous awards for design. Resources directly available to the master's program in architecture include graduate faculty members from the Departments of Landscape Architecture and Product Design, as well as from related fields such as social sciences and engineering. The possibilities for interdisciplinary studies with these faculty members are a major strength of the program.

The recent establishment of the Center for Environmental Design as the official research and service agency of the School provides a highly visible and flexible mechanism to facilitate the School's mission in this vitally important area of faculty and student activity. The Center will make it possible for the School of Design to pursue a far more active role in funded research and development, community service and continuing education.

The Department of Architecture has access to all the facilities in the School of Design, which is housed in Brooks Hall. Design studios, lecture and seminar rooms, extensive shop facilities, well equipped visual and photographic laboratories, exhibition and lounge spaces and a large design research laboratory are available in the School of Design for graduate studies. In addition, the School of Design Library has a large and fast-growing collection of books and slides and constitutes an important resource center for the graduate program in architecture.

Research assistantships and fellowships are available for qualified applicants. A bulletin and pertinent information describing in detail opportunities for graduate study and research in the Department of Architecture, including the urban design program, are available upon request from the head of the department.

FOR ADVANCED UNDERGRADUATES

ARC 400 INTERMEDIATE ARCHITECTURAL DESIGN (SERIES) 4(1-9) FS
Prerequisite: DN 202 or equivalent or consent of department

Design investigations aimed at the development of an understanding of the major issues confronting the contemporary architect and at the expanding of problem solving abilities in architectural design. Students must complete four semesters to satisfy this requirement, selecting from a number of vertically organized workshops which offer on an optional basis a wide range of program emphases.

ARC 431 INDUSTRIALIZED SYSTEM BUILDING 2(1-3) FS
Prerequisite: ARC 331

An analytic study of mass produced building systems to examine the implications, limitations and potentials of this type of architecture. The analysis is to include design, factory processes, distribution methods, fabrication, erection and economic analysis.

ARC 432 CLIMATE CONTROL SYSTEMS AND DESIGN 2(1-3) F
Prerequisite: ARC 332

Further study of the mechanical systems used for heating, cooling, ventilating and conditioning the interior of the buildings. The analysis and design of the climate control system for a small scale building will be undertaken in this course.

ARC 433 ILLUMINATION DESIGN 2(1-3) S
Prerequisite: ARC 332

Examination of interior and exterior lighting design, including vision, color, sources and control.

ARC 441 DESIGN METHODS 2(2-0) FS

Description, comparisons and testing of the various methods which are available in architectural design with emphasis on problem-solving techniques. The method is primarily a means for integrating rational analysis and creative thought in the design act.

ARC 491 SPECIAL PROJECTS IN ARCHITECTURE 1-4 FS
Prerequisite: Junior standing

Investigation of special projects by interdisciplinary groups or individuals in various phases of architecture.

ARC 495 SPECIAL PROBLEMS IN ARCHITECTURE 1-3 FS
Prerequisite: Junior standing

Special problems in various aspects of architecture developed under the direction of a faculty member on a tutorial basis.

ARC 499 ARCHITECTURE SEMINAR 1-3 FS
Prerequisite: Departmental approval

Presentations and discussions of special areas of interest in architecture and the allied design fields.

FOR GRADUATES AND ADVANCED UNDERGRADUATES

ARC 501, 502 ADVANCED ARCHITECTURAL DESIGN I, II 6(3-9) FS
Prerequisites: (501) 16 credits of ARC 400 or equivalent; (502) ARC 501

Advanced studies in architectural design in which are investigated large-scale architectural problems having complex functional, social and economic implications; special emphasis is given to problem identification, program formulation and application of advanced design methods.

ARC 511 PROFESSIONAL PRACTICE I 2(2-0) F
Prerequisite: Fourth year standing

The evolution of architecture as a modern practical profession; obligations of the profession to society and to itself; the legal and ethical position of the architect in practice; comparative study of documents; the architect's working organization; emerging techniques of office practice.

ARC 512 PROFESSIONAL PRACTICE II 2(2-0) S
Prerequisite: Fourth year standing

Continuing study of standard documents and emerging techniques of practice, with emphasis on the principles and improved techniques of writing construction specifications; interrelationship of The Contract Documents; comparative study of techniques for controlling competitive bidding.

ARC 521, 522 ARCHITECTURAL STRUCTURES I, II 3(3-0) FS
Prerequisites: (521) CE 339; (522) ARC 521

Gravity and non gravity loads on structures; comparative behavior of structural materials; comparative behavior of simple structural systems; approximate and exact analysis procedures as applied to systems; principles of approximate and exact design in timber, steel and reinforced concrete; architectural/structural/mechanical compatibility in systems; basic principles of foundation analyses and design.

ARC 531, 532 ADVANCED BUILDING TECHNOLOGY I, II 2(1-3) FS
Prerequisites: (531) ARC 331, 332; (532) ARC 331, 332

A synthesis of studies in building science undertaken in previous courses. Material assemblies in practical applications, dimensional characteristics of mechanical and construction systems for buildings, and special projects in selected areas of building science.

ARC 551 RESEARCH METHODS IN ARCHITECTURE 2(2 0) FS
Prerequisite: Graduate standing

Seminar on the quantitative methods from various disciplines towards the scientific inquiry of knowledge. Analysis of techniques and instruments appropriate in solving problems involving scaling, measurement, modeling and gaming within the scope of the physical environment.

FOR GRADUATES ONLY

ARC 601, 602 ADVANCED ARCHITECTURAL DESIGN III, IV 6(3-9) FS
Prerequisites: (601) ARC 502; (602) ARC 601

Continuing advanced studies in architectural design in which are synthesized all previous design experience through in-depth investigations of significant environmental problems. Consultation with planners and environmental specialists is extensive. A terminal project is developed in the spring semester.

ARC 621, 622 ARCHITECTURAL STRUCTURES III, IV 2(1-3) FS
Prerequisites: (621) ARC 522; (622) ARC 621

Special projects in the study of complex structural systems: cable structures, membranes, thin shells, folded plates, arches, vaults, space frames; studies of construction techniques, pre fabrication, structural behavior and stress analysis through model work and simplified calculation procedures.

ARC 691, 692 SPECIAL TOPICS IN ARCHITECTURE 1-6 FS
Prerequisite: Graduate standing

An investigation of special topics in architecture of particular interest to advanced students under the direction of a faculty member on a tutorial basis. Credits and content will vary with the needs of students.

Biochemistry

GRADUATE FACULTY

Professor GENNARD MATRONE, *Head*
Professors: FRANK B. ARMSTRONG, JOSEPH S. KAHN, IAN S. LONGMUIR, A. RUSSELL MAIN, SAMUEL B. TOVE; *Associate Professors:* H. ROBERT HORTON, EDWARD C. SISLER; *Assistant Professors:* JAMES A. KNOPP, ELIZABETH C. THEIL

ASSOCIATE MEMBERS OF THE DEPARTMENT

Professor: LEONARD W. AURAND; *Associate Professors:* EVAN E. JONES, WILLIAM P. TUCKER; *Assistant Professor:* JON BORDNER

The field of biochemistry applies and extends the concepts of chemistry and physics to the investigation of biological problems. The Department of Biochemis-

try offers courses of study leading to the degrees, Master of Science and Doctor of Philosophy.

A student entering into graduate study in biochemistry should have a bachelor's degree in chemistry or in a biological science. The undergraduate program of studies should include a minimum of two semesters of organic chemistry, two semesters of physical chemistry, one semester of quantitative analytical chemistry and one semester of qualitative organic analysis. Students who lack undergraduate courses considered essential for graduate study in biochemistry may be admitted to the graduate program, provided the deficiencies are corrected early in their graduate work.

Courses in General and Experimental Biochemistry and in Intermediary Metabolism are required as part of the program leading to advanced degrees in biochemistry. In addition to completing a program of study approved by his advisory committee, a candidate for an advanced degree is expected to participate regularly in seminars throughout his graduate residence and to engage in independent research leading to the completion of a scholarly thesis. Research programs are currently being conducted in biochemical genetics, enzyme structure and mechanisms, enzyme kinetics, biochemical aspects of toxicology, mechanisms of control, photosynthesis and electron transport, biosynthesis of alkaloids, lipid metabolism, metabolism and function of transition elements, physical biochemistry of macromolecules, oxygen transport mechanisms, and regulation of protein synthesis during development.

FOR ADVANCED UNDERGRADUATES

BCH 452 EXPERIMENTAL BIOCHEMISTRY 3(1-6) F
Prerequisite: BCH 351, or corequisite BCH 551; quantitative chemical analysis recommended

An introduction to fundamental techniques of biochemistry and molecular biology involving experimental study of carbohydrates, proteins, enzymes, nucleic acids, lipids, metabolism and metabolic controls. Designed to accompany BCH 551. Mrs. Theil

FOR GRADUATES AND ADVANCED UNDERGRADUATES

BCH 551 GENERAL BIOCHEMISTRY 3(3-0) F
Prerequisites: Three years of chemistry including CH 223; CH 341 strongly recommended

Principles of modern biochemistry including a study of structural and metabolic relationships of carbohydrates, lipids, proteins, nucleic acids, enzymes and coenzymes. Designed to accompany BCH 452. Mr. Jones

BCH 553 (PHY 553) PHYSIOLOGICAL BIOCHEMISTRY 3(3 0) S
Prerequisite: BCH 551

Emphasis on the application of biochemical methods to the elucidation of the function of whole organisms. In particular, A. Biochemistry of 1) blood, 2) water, electrolyte, acid-base balance, 3) renal function, 4) muscle metabolism, 5) central nervous system, 6) autonomic nervous system, 7) endocrine system. B. Biochemistry of adaptation to environment 1) high and low P_{02}, 2) hot and cold, 3) wet and dry, 4) pollution. Mr. Longmuir

BCH 554 RADIOISOTOPE TECHNIQUES IN BIOLOGY 2(1-3) F
Prerequisite: BCH 551 or CH 433 or CH 435

The theory and application of radioisotope techniques used in biology. The different modes of radioactivity are correlated with methods of measurement. Emphasis is placed on the use and limitations of various instruments and techniques and on their application to research problems. Mr. Sisler

BCH 557 INTRODUCTORY ENZYME KINETICS 3(3-0) S
Prerequisites: BCH 551 and MA 201 or MA 212

The basic principles of chemical kinetics applied to the development of enzyme kinetics. Limitations of the Michaelis equation are considered in light of the general rate equation. Inhibition and activation, pH functions, effects of temperature, and elucidation of mechanisms are also considered. Mr. Main

BCH 561 (GN 561, MB 561) BIOCHEMICAL AND MICROBIAL GENETICS 3(3-0) F
Prerequisites: BCH 351 or BCH 551, GN 411 or GN 505, MB 401 or equivalent

A study of the development of the fields of biochemical genetics and microbial genetics, emphasizing both techniques and concepts currently used in research in these areas. Includes lectures and discussions of current research publications.
Mr. Armstrong

BCH 590 SPECIAL TOPICS IN BIOCHEMISTRY Maximum 3 FS Sum.
Prerequisite: BCH 351 or equivalent

The study of topics of special interest by small groups of students instructed by members of the faculty, usually for the purpose of developing new courses.
Graduate Staff

FOR GRADUATES ONLY

BCH 651 PHYSICAL BIOCHEMISTRY 3(3-0) S
Prerequisites: BCH 551, CH 331 or CH 431, or consent of instructor.

Structural and physical properties of biological macromolecules and the application of physical methods to their study. Mr. Knopp

BCH 652 BIOCHEMICAL RESEARCH TECHNIQUES 3-5 S
Prerequisites: BCH 551; BCH 452 or CH 315 or CH 411

Laboratory projects involving separation and characterization of biochemical constituents including enzymes. Mr. Kahn

BCH 653 (ANS 653) MINERAL METABOLISM 3(3-0) F
Prerequisite: BCH 551

Principles of mineral metabolism with emphasis on metabolic functions, reaction mechanisms and interrelationships. Mr. Matrone

BCH 655 INTERMEDIARY METABOLISM I 3(3-0) S
Prerequisite: BCH 551

Lectures covering enzyme kinetics, energetics, and the metabolism of carbohydrates and lipids. Mr. Tove

BCH 657 INTERMEDIARY METABOLISM II 3(3-0) F
Prerequisite: BCH 551

Lectures covering enzyme mechanisms, metabolism of proteins, nucleic acids, and their constituents, and metabolic controls. Mr. Horton

BCH 659 (CH 659) NATURAL PRODUCTS 3(3-0) F
(See chemistry, page 97.)

BCH 691 SEMINAR IN BIOCHEMISTRY 1 FS
Graduate Staff

BCH 695 SPECIAL TOPICS IN BIOCHEMISTRY Credits Arranged
Prerequisite: Graduate standing in biochemistry

Critical study of special problems and selected topics of current interest in biochemistry and related fields. Graduate Staff

BCH 699 BIOCHEMICAL RESEARCH Credits Arranged
Graduate Staff

Biological and Agricultural Engineering

GRADUATE FACULTY

Professor FRANCIS J. HASSLER, *Head*
Professors: HENRY D. BOWEN, DAVID H. HOWELLS, WILLIAM H. JOHNSON, CHARLES W. SUGGS; *Professor USDA:* JAMES W. DICKENS; *Associate Professors:* ROBERT G. HOLMES, BARNEY K. HUANG, ERVIN G. HUMPHRIES, GEORGE J. KRIZ, WILLIAM F. MCCLURE, EDWARD H. WISER, JAMES H. YOUNG; *Associate Professors USDA:* THOMAS B. WHITAKER, CLIFF R. WILLEY, RALPH E. WILLIAMSON; *Assistant Professors:* FRANK J. HUMENIK, ROGER P. ROHRBACH, RICHARD W. SKAGGS, ROBERT E. SOWELL

ASSOCIATE MEMBERS OF THE DEPARTMENT

Associate Professors: DONALD D. HAMANN, VICTOR A. JONES

The Department of Biological and Agricultural Engineering offers programs of study for the Master of Science, Doctor of Philosophy and Master of Biological and Agricultural Engineering degrees. A bachelor's degree in engineering from an accredited curriculum or its equivalent provides the necessary background for graduate study.

For those interested primarily in a broadened background of engineering science and technology without the thesis requirement, the Master of Biological and Agricultural Engineering program permits a wide selection from a variety of advanced courses. Such study is appropriate to certain supervisory and managerial positions, advanced design and development, technical sales, service and promotional work. While this program is primarily for those intending to terminate graduate study in engineering at the master's level, a student may, with departmental approval, develop a plan of study under this program which leads to study for the doctorate.

The Master of Science program takes into account the increasing rigor of modern science and engineering. Emphasis here is on mathematics and theory as the unifying link between otherwise widely divergent fields of knowledge in the biological and physical sciences, and as prerequisites to effective engineering advances in biological and agricultural areas. As the student acquires competence in the advanced methods of science, he applies his knowledge by conducting an original research investigation and by writing and defending a thesis.

Study for the Doctor of Philosophy degree builds on the Master of Science program with an additional year of formal study followed by a period of independent research to satisfy dissertation requirements. Doctoral research is expected to be an original and valuable addition to the existing body of scientific and technical knowledge.

Unusual opportunities are available for graduate student participation in departmental research programs. Current projects include: watershed hydrology; drainage and irrigation; functional development of field machinery; fruit and vegetable mechanization; pesticide application; plant growth dynamics; crop process engineering and materials handling; biophysics of agricultural processing; human engineering; operations research; computer simulation analysis of biological and physical systems; biological instrumentation; physical properties of biomaterials; engineering aspects of plant and animal physiology; and waste management.

Graduate students have access to modern well-equipped research laboratories, controlled-environment test chambers, a research shop manned by competent mechanics, and excellent analog and digital computing facilities.

Information concerning fellowships and assistantships may be obtained from the head of the department.

FOR ADVANCED UNDERGRADUATES

BAE 411 FARM POWER AND MACHINERY 3(2-3) S
Prerequisites: BAE 211, PY 211 or PY 221

This course covers the application of heat engineering principles in the development and utilization of power of internal combustion engines, both spark ignition and diesel. Included are thermodynamic principles and a classification of these to the actual design and construction of engines, together with principles of carburetion and ignition. Power transmission units, hydraulics and hydraulic controls are emphasized. Power measurement and testing, and the economic utilization of power units are brought into the context of modern agriculture.

Mr. Fore

BAE 433 CROP PRESERVATION AND PROCESSING 3(2-3) F
Prerequisite: BAE 341

This course deals with the physical and biochemical characteristics of harvested crops and crop products as they define the requirements for the best preservation of quality. The properties of air-water vapor mixtures, the application of heat to air and crops, the characteristics and use of fans and heaters, the air flow requirements and measurement for crop preservation and materials handling will be studied. Feed preparation, mixing and handling are included in the course.

Mr. Glover

BAE 451, 452 AGRICULTURAL ENGINEERING DESIGN I, II 3(1-6) FS
Prerequisite: Senior standing in SBE curriculum

Design concepts are applied to current agricultural engineering problems. One major design project is combined with a variety of case studies and short term design problems to develop the student's confidence in his ability to do design work. Mr. Holmes

BAE 461 ANALYSIS OF ARGICULTURAL PRODUCTION SYSTEMS 3(3-0) F
Prerequisites: MA 201, EC 205, ST 361

Survey of methods of systems analysis for agricultural engineering students.

Intermediate economics analysis, with particular emphasis on farm machinery economics; materials-handling problems; activity network and scheduling problems; techniques of obtaining and processing systems data. Mr. Sowell

BAE 462 FUNCTIONAL DESIGN OF FIELD MACHINES 3(2-2) S
Prerequisites: BAE 361, MAE 301, SSC 200

A study of the modern farm tractor and field machines. The emphasis of the course is on the translation of measurements of biological and physical factors of the agricultural production system into machine specifications that can be effectively converted into production machines by engineers of the manufacturing industry. Mr. Bowen

BAE 472 AGRICULTURAL WATER MANAGEMENT 4(3-2) F
Prerequisites: BS 100, SSC 200

Aspects of hydrology and soil-water-plant relationships as related to agricultural water management. Drainage and irrigation are discussed in depth. Water quality, agricultural related pollution and water laws are discussed. Mr. Skaggs

FOR GRADUATES AND ADVANCED UNDERGRADUATES

BAE 552 INSTRUMENTATION FOR AGRICULTURAL RESEARCH AND PROCESSING 2(1 3) Alternate F
Prerequisites: EE 331, MA 301

Theory and application of primary sensing elements and transducers. Generalized performance characteristics and the use of standards. Use of specialized measurement systems for agricultural research and processing including an introduction to correlation and power spectral density measurements. Mr. Rohrbach

BAE 570 (CE 570, MB 570) SANITARY MICROBIOLOGY 3(2-3) S
Prerequisite: MB 401 or equivalent

Fundamental aspects of microbiology and biochemistry are presented and related to problems of stream pollution, refuse disposal and biological treatment. Laboratory exercises present basic microbiological techniques and illustrate from a chemical viewpoint some of the basic microbial aspects of waste disposal.
Mr. Humenik

BAE 578 (CE 578) AGRICULTURAL WASTE MANAGEMENT 3(2-3) F
Prerequisite: Graduate or advanced undergraduate standing

A study of agricultural and associated processing wastes. Special laboratory techniques required for the characterization of these wastes will be emphasized. Principles and examples considered will be utilized to develop waste management and nondestructive waste utilization systems that are integral to the total operation. Mr. Humenik

BAE 580 ANALYSIS OF THE PHYSICAL PROPERTIES OF BIOMATERIALS 3(2-2) Alternate S
Prerequisites: PY 205, PY 208

Physical characteristics—shape and size, volume and density, and surface area of biomaterials. Aero- and hydro-dynamic characteristics (drag coefficient and terminal velocity) and dimensional analysis. Friction (static and rolling), particle mechanics and gravity and forced particle flow. Thermal properties (expansion and conductivity, specific heat), electrical properties (resistance and conductance, dielectric and electrostatic behavior), optical properties using transmittance and reflectance, and x-ray and laser. Graduate Faculty

BAE 585 BIORHEOLOGY 3(2-2) Alternate S
Prerequisites: PY 205, EM 301

The concepts of strain, stress and the mechanical viscoelastic properties of biological solids, fluids and slurries. The time-dependent deformation and flow of biomaterials, elements of strength of materials, rheological equations and model concepts, creep-relaxation and dynamic behavior, contact problems and the Boltzman superposition principle as a function of time, temperature and moisture content. Mr. Hamann

BAE 590 SPECIAL PROBLEMS Credits Arranged
Prerequisite: Senior or graduate standing in agricultural engineering

Each student will select a subject on which he will do research and write a technical report on his results. He may choose a subject pertaining to his particular interest in any area of study in biological and agricultural engineering.
Graduate Staff

FOR GRADUATES ONLY

BAE 654 NONEQUILIBRIUM THERMODYNAMICS IN BIOENGINEERING 3(3-0) Alternate S
Prerequisite: MA 511

Generalized classical thermodynamics is extended by Onsager's relations to provide a theoretical basis for analyzing the energetics of systems that include life processes. Topics illustrate applications to special systems including isothermal diffusion and sedimentation, membrane permeability, transport processes in continuous systems, and systems with temperature gradients. Mr. Johnson

BAE 661 ANALYSIS OF FUNCTION AND DESIGN OF BIOLOGICAL AND PHYSICAL SYSTEMS 3(2-3) Alternate F
Prerequisite: Consent of instructor

The course attempts to develop those mathematical and analytical techniques and principles found to be essential in the analysis and design of machines and systems which encompass both the biological and the physical domains and their interfaces. Analytical treatment of physical and biological systems and the functional analysis of machine components are studied to bridge the gap between theories and applications. Control systems synthesis and design are treated with emphasis on quantitative dynamic relations between elements and system response using transfer function and computer simulation techniques.
Messrs. Bowen, Huang

BAE 671 (SSC 671) THEORY OF DRAINAGE—SATURATED FLOW 3(3-0) Alternate F
Prerequisite: MA 513

Physical concepts and properties of fluids and porous media are discussed in relation to soil water movement. The fundamental laws and equations governing saturated flow in porous media are derived and discussed. Mathematical solutions of steady-state and transient flow equations are analyzed to determine their applicability to drainage problems. Analogs and models of particular drainage problems are considered. Mr. Skaggs

BAE 674 (SSC 674) THEORY OF DRAINAGE—UNSATURATED FLOW 3(3-0) Alternate F
Prerequisite: BAE 671 or equivalent

Forces involved and theories utilized in saturated flow of porous media are discussed in relation to soil moisture movement. Steady-state and transient unsaturated flow equations for horizontal and vertical moisture movement are

developed and solved. The solutions are applied to present-day laboratory and field technology. Molecular diffusion and hydrodynamic dispersion are considered in light of current tracing techniques. Mr. Skaggs

BAE 695 SEMINAR 1(1-0) FS
Prerequisite: Graduate standing in biological and agricultural engineering

Elaboration of the subject areas, techniques and methods peculiar to professional interest through presentations of personal and published works; opportunity for students to present and critically defend ideas, concepts and inferences. Discussions to point up analytical solutions and analogies between problems in biological and agricultural engineering and other technologies, and to present the relationship of biological and agricultural engineering to the socioeconomic enterprise.
Mr. Rohrbach

BAE 699 RESEARCH IN BIOLOGICAL AND AGRICULTURAL ENGINEERING Credits Arranged
Prerequisite: Graduate standing in biological and agricultural engineering

Performance of a particular investigation of concern to biological and agricultural engineering. The study will begin with the selection of a problem and culminate with the presentation of a thesis. Graduate Staff

Biological Sciences

Professor J. L. APPLE, *Assistant Director of Academic Affairs and Research for the Biological Sciences*
Associate Professor CHARLES F. LYTLE, *Teaching Coordinator*

There is no graduate major per se in the biological sciences, but a number of interdepartmental instructional activities are coordinated through the School of Agriculture and Life Sciences. There are several courses at the graduate level which are interdepartmental or interdisciplinary in scope and which are applicable to several graduate major and minor programs. These courses are described below.

BS 500 (HI 500) THE DEVELOPMENT OF CONTEMPORARY CONCEPTS IN BIOLOGY 3(3-0) S
Prerequisite: General biology

Selected contemporary concepts of biology are traced from their origins. Considerable attention is given to the lives of the men who have made important contributions to the development of these concepts.

BS 590 SPECIAL PROBLEMS IN BIOLOGICAL INSTRUMENTATION 1-3 FS
Prerequisite: Consent of instructor

This course comprises a series of instructional sections, each of five weeks duration, devoted to the principles and concepts of biological instrumentation. Each five-week instructional section carries one semester credit. Advanced undergraduate and graduate students may register for only one or up to three sections (total of three credits) per semester. The sections currently offered cover the following topics: basic components of spectrophotometers including light sources, dispersing devices, detectors and read-out methods; theoretical and practical aspects of electron microscopy; basics of analog and digital computing methods and applications of computers to biological research; methods of separation and identification of biopolymers; principles of measurement; and the application of electronics in biological measuring and sensing devices. (For specific information on instructional sections offered, scheduling and instructors, contact the Biological Sciences Office.)

BS 690 SEMINAR IN CELL BIOLOGY 1(1-0) S
Prerequisites: Graduate standing, background in biology or chemistry

A topical appraisal of the current literature in selected areas of cell biology through presentations and discussions by students, faculty and visiting scientists.

BS 696 TOPICS IN BIOLOGICAL ULTRASTRUCTURE 1(1-0) F
Prerequisite: Graduate standing (background preferably in biology)

A survey of the ultrastructure of living organisms from viruses to higher plants and animals by means of illustrated lectures. The changes in fine structure associated with differentiating cells and with cells in various metabolic states are examined.

Biomathematics

(For a listing of graduate faculty and departmental information see statistics, page 297.)

FOR GRADUATES AND ADVANCED UNDERGRADUATES

BMA 493 SPECIAL TOPICS IN BIOMATHEMATICS 1-3 FS
Prerequisite: Consent of instructor

Directed readings, problem sets, written and oral reports at an introductory level as dictated by need and interest of student; new 400-level courses during the developmental phase. Staff

BMA 501 THEORETICAL BIOCHEMISTRY I 3(3-0) F
Prerequisites: MA 405, CH 433, BCH 551 or consent of instructor

Application of physical theory and mathematics to biochemistry. Examination of basic principles of molecular theory, reaction rate theory, statistical mechanics and nonequilibrium thermodynamics as applied to biochemical systems. (Offered fall 1973 and alternate years.) Mr. Gold

BMA 502 THEORETICAL BIOCHEMISTRY II 3(3-0) S
Prerequisite: BMA 501

Continuation of BMA 501. Coupling of diffusion and chemical reactions. Mathematical description of enzyme control, coupled sequences of enzyme reactions, feedback loops and oscillatory reactions. Experimentally oriented topics include theory of chemical relaxation and tracer dynamics. (Offered spring 1972 and alternate years.) Mr. Gold

BMA 571 (MA 571, ST 571) BIOMATHEMATICS I 3(3-0) F
Prerequisites: Advanced calculus, reasonable background in biology or consent of instructor

The role of theory construction and model building in the development of experimental science. Induction vs. deduction. The historical development of mathematical theories and models for the growth of one-species populations (logistic and offshoots), including consideration of age distributions (matrix theory, Leslie and Lopez; continuous theory, Lotka). Some of the more elementary theories on the growth of organisms (von Bertalanffy, with applications to ecology; allometric theories, cultures grown in a chemostat). Mathematical theories of two and more species systems (predator-prey, competition, symbiosis; according to the Volterra-Lotka schemes, including present-day research), and discussion of some related models for chemical reaction kinetics. Much emphasis is placed on scrutiny of the biological concepts as well as of the mathematical structure of the models in order

to uncover both weak and strong points of the models discussed. Mathematical treatment of the differential equations in these models stresses qualitative and geometric aspects. Mr. van der Vaart

BMA 572 (MA 572, ST 572) BIOMATHEMATICS II 3(3-0) S
Prerequisites: BMA 571, elementary probability theory

Continuation of topics of BMA 571. Some more advanced mathematical techniques concerning nonlinear differential equations of the types encountered in BMA 571: several concepts of stability, asymptotic directions, periodic models. Comparison of deterministic and stochastic models for several biological problems including birth and death processes. Certain aspects of linear system theory (time-invariant and variable models) used for the analysis of biological systems. Discussion of various applications of mathematics to biology, e.g., theories of aging, some recent research. Mr. van der Vaart

BMA 591 SPECIAL TOPICS 1-3 FS
Prerequisite: Consent of instructor

Directed readings, problem sets, written and oral reports as dictated by need and interest of student; new 500-level courses during the developmental phase.
Graduate Staff

FOR GRADUATES ONLY

BMA 691 ADVANCED SPECIAL TOPICS 1-3 FS
Directed readings, problem sets, written and oral reports as dictated by need and interest of student; new 600-level courses during the developmental phase.
Graduate Staff

BMA 694 SEMINAR 1(1-0) FS
Prerequisite: Graduate students in biomathematics are expected to attend throughout the period of their residence.

BMA 699 RESEARCH Credits Arranged FS

Botany

GRADUATE FACULTY

Professor GLENN RAY NOGGLE, *Head*
Professors: ARTHUR W. COOPER, (on leave), ROBERT J. DOWNS, JAMES W. HARDIN, HERBERT T. SCOFIELD (Peru), JAMES R. TROYER; *Adjunct Professor:* WALTER W. HECK; *Professors Emeritus:* BERTRAM W. WELLS, LARRY A. WHITFORD; *Associate Professors:* CHARLES E. ANDERSON, ROYALL T. MOORE, HAROLD E. SCHLICHTING, JR.; *Adjunct Associate Professor:* HAROLD L. LEWIS; *Adjunct Associate Professor USDA:* DONALD W. DEJONG; *Associate Professors USDA:* HAROLD E. PATTEE, HEINZ SELTMANN, RALPH E. WILLIAMSON; *Assistant Professors:* UDO BLUM, ROGER C. FITES, ERNEST D. SENECA, C. GERALD VAN DYKE

ASSOCIATE MEMBERS OF THE DEPARTMENT

Professors: JOSEPH S. KAHN, RICHARD J. THOMAS, DAVID H. TIMOTHY; *Professor USDA:* DONALD E. MORELAND; *Associate Professor:* BILLY J. COPELAND

The Department of Botany offers programs leading to the Master of Botany (non-thesis), Master of Science and Doctor of Philosophy degrees.

Excellent physical facilities and equipment are available for instruction and research in all phases of the departmental program. The Phytotron (part of a two-unit controlled environment facility operated in collaboration with Duke University) offers unexcelled opportunities for research in experimental taxonomy, ecology and plant physiology. An electron microscope laboratory is available. A fine herbarium supports studies in systematics, and is augmented by the herbaria in the Departments of Botany in nearby Duke University and the University of North Carolina at Chapel Hill. The availability in North Carolina of a wide range of habitats with an accompanying diversity of flora provides opportunities for field problems in ecology, mycology, phycology and biosystematics. Field laboratories are available at the coast, in the Piedmont and in the mountains. The facilities of 16 branch Agricultural Experiment Stations also are available for field studies. The department participates in tropical biology programs through membership in the Organization for Tropical Studies.

Air and water pollution programs have been developed in the School of Agriculture and Life Sciences and the School of Engineering at North Carolina State University in collaboration with groups at Duke University and the University of North Carolina at Chapel Hill.

Strong supporting programs in biology are available in other departments on the campus—forest resources, soil science, plant pathology, microbiology, zoology, crop science, biochemistry, statistics, biomathematics and genetics. Students also may enroll in botany courses offered at Duke University and the University of North Carolina at Chapel Hill.

FOR ADVANCED UNDERGRADUATES

BO 400 PLANT DIVERSITY 3(2-3) F
Prerequisite: BO 200 or equivalent

A comprehensive survey of the evolutionary diversity and phylogeny of the plant kingdom. Emphasis is placed on the evolutionary trends and the basis for assumed relationships, considering fossils as well as living forms. Some time is spent observing plants in their native habitats, and on a consideration of adaptations to various environments and modes of existence.

BO 402 (CS 402) ECONOMIC BOTANY 3(2-3) S
Prerequisite: BO 200

Emphasis is on plants and human affairs, rather than taxonomy, production or economics. Discussions center on all phases of the interrelationships of the plant world and the life history of incipient to modern human cultures. Treatment includes plants and plant products, beneficial and harmful, that man has used as necessities of life, as ameliorants contributing to his well-being, and as raw materials for industry. Ornamentals are excluded.

BO 403 SYSTEMATIC BOTANY 4(2-4) S
Prerequisite: BS 100 or BO 200

A systematic survey of vascular plants emphasizing field identification, terminology and general evolutionary relationships.

BO 414 (ZO 414) CELL BIOLOGY 4(3-3) F
Prerequisites: CH 223, PY 212

A study of the chemical and physical bases of cellular structure and function with emphasis on methods and interrelationships.

BO 421 PLANT PHYSIOLOGY 4(3-3) S Sum.
Prerequisites: BS 100 or BO 200 and year of chemistry

Physiology of the green plant emphasizing plant organization, water and solute relationships, organic and inorganic nutrition, growth and development.

FOR GRADUATES AND ADVANCED UNDERGRADUATES

BS 500 (HI 500) THE DEVELOPMENT OF CONTEMPORARY CONCEPTS IN BIOLOGY
(See biological sciences, page 79.) 3(3-0) S

BO 510 PLANT ANATOMY 4(2-6) F
Prerequisite: BO 200

A study of the cells, tissues and organs of common flowering plants and gymno sperms. Growth and differentiation patterns will be considered with emphasis on current research. (Offered 1972-73 and alternate years.) Mr. Anderson

BO 522 ADVANCED MORPHOLOGY AND PHYLOGENY OF SEED PLANTS 4(3-3) S
Prerequisite: BO 403

A comprehensive survey of the morphology and evolution of angiosperms and gymnosperms. Special emphasis is given to detailed vegetative and reproductive morphology of fossil and living forms, and to their presumed evolutionary relationships. (Offered 1971-72 and alternate years.) Mr. Hardin

BO 524 GRASSES, SEDGES, AND RUSHES 4(2 6) F
Prerequisite: BO 403

A course dealing with three large, economically and ecologically important plant families. A working familiarity with these three groups will be achieved through an introduction to the special terminology used in dealing with these plants, extensive field work emphasizing keying out plants collected, and a study of the recently developed modern classification of the grasses. (Offered 1971-72 and alternate years.) Mr. Koch

BO 544 PLANT GEOGRAPHY 3(3-0) S
Prerequisites: BO 403, BO 360 (ZO 360), GN 411 or equivalents

A course in descriptive and interpretive plant geography, synthesizing data from the fields of ecology, genetics, geography, paleobotany and taxonomy. Includes a survey of the present distribution of major vegetation types throughout the world, a discussion of the history and development of this present pattern of vegetation and a discussion of the principles and theories of plant geography. (Offered 1972-73 and alternate years.) Mr. Cooper

BO 551 ADVANCED PLANT PHYSIOLOGY I 3(3-0) F
Prerequisites: General botany or biology, and biochemistry

The first half of a two-semester sequence covering the current status of plant physiology. Topics will include plant organization, metabolism, water relations, solute relations, photobiology and respiration. Messrs. Troyer and Noggle

BO 552 ADVANCED PLANT PHYSIOLOGY II 3(3 0) S
Prerequisites: General botany or biology, and biochemistry

The second half of a two-semester sequence covering the current status of plant physiology. Topics will include inorganic nutrition, nitrogen assimilation, plant growth substances, physiology of seeds, vegetative growth, reproductive growth, aging and senescence. Messrs. Noggle and Troyer

BO 553 LABORATORY IN ADVANCED PLANT PHYSIOLOGY I 1(0-3) F
Prerequisite or corequisite: BO 551

Laboratory to accompany BO 551 Advanced Plant Physiology I. Laboratory procedures in plant nutrition, plant structure and composition, water relations, respiration. Staff

BO 554 LABORATORY IN ADVANCED PLANT PHYSIOLOGY II 1(0-3) S
Prerequisite or corequisite: BO 552

Laboratory to accompany BO 552 Advanced Plant Physiology II. Laboratory procedures in enzymes, photosynthesis, photobiology, plant growth substances. Staff

BO 560 (ZO 560) PRINCIPLES OF ECOLOGY 4(3-3) F
Prerequisite: Three semesters of college level biology courses

A consideration of the principles of ecology at the graduate level. Each of the major subject areas of ecology is developed in sufficient depths to provide a factual and philosophical framework for the understanding of ecology. Messrs. Blum and Standaert

BO 561 PHYSIOLOGICAL ECOLOGY 4(3-3) S
Prerequisites: BO 421 and BO 560 (ZO 560) or equivalent

This course will approach the plant community from a physiological standpoint. Emphasis will be placed on the individual in the community and how it responds to its immediate environment on a short- and long-term basis. (Offered 1972-73 and alternate years.) Mr. Blum

BO 574 (MB 574) PHYCOLOGY 3(1-4) S
Prerequisite: BS 100 or BO 200

An introduction to the structure, reproduction and importance of organisms which may be included in the algae. Considerable time is devoted to the local freshwater and marine floras and the ecology of important species. Mr. Schlichting

BO 575 (MB 575, PP 575) THE FUNGI 3(3-0) S
Prerequisite: BO 200 or equivalent

An overview of the fungi within the framework of a survey of the major classes. Lectures while covering the major groups systematically will also include ancillary material on aspects of ultrastructure, experimental adaptations, sexuality, ontogeny, and economic, including historical, importance. Mr. Moore

BO 576 (MB 576, PP 576) THE FUNGI—LABORATORY 1(3-0) S
Corequisite: BO 575

The course will provide illustrative material of the fungal assemblages discussed in BO 575. Mr. Moore

BO 590 TOPICAL PROBLEMS 1-3 FS
Prerequisite: Consent of instructor

Discussions and readings on problems of current interest in the fields of ecology,

anatomy and morphology, taxonomy, and cell biology. May be repeated with a change in topic for a maximum of six credits. Graduate Staff

FOR GRADUATES ONLY

BO 612 PLANT MORPHOGENESIS 4(3-3) F
Prerequisite: Six hours of botany equivalent to BO 400 and BO 421

A review and synthesis of the factors involved in the development of plant form. Levels of control from the molecular to the whole organism will be considered. (Offered 1971-72 and alternate years.) Mr. Anderson

BO 620 ADVANCED TAXONOMY 3(2 2) S
Prerequisite: BO 403

A course in the principles of plant taxonomy including the history of taxonomy, systems of classification, rules of nomenclature, taxonomic literature, taxonomic and biosystematic methods, and monographic techniques. (Offered 1972-73 and alternate years.) Mr. Hardin

BO 625 (PP 625) ADVANCED MYCOLOGY 4(2-6) F
(See plant pathology, page 262.)

BO 631 WATER RELATIONS OF PLANTS 3(3-0) S
Prerequisite: BO 551 or equivalent

A discussion of the physiological water relations of plants with emphasis on theoretical principles and quantitative description. (Offered 1972-73 and alternate years.) Mr. Troyer

BO 633 PLANT GROWTH AND DEVELOPMENT 3(3-0) S
Prerequisites: BO 414 (ZO 414) or BO 421, organic chemistry

An advanced course in plant physiology covering plant growth, development, differentiation, senescence and biological control mechanisms. Mr. Fites

BO 634 INTRODUCTION TO THE THERMODYNAMICS OF BIOLOGICAL SYSTEMS 3(3-0) S
Prerequisite: BO 551 or consent of instructor

An introductory development of the thermodynamic theory relevant to biological systems together with consideration of examples of biological problems to which thermodynamic theory has been applied. (Offered 1971-72 and alternate years.) Mr. Troyer

BO 636 DISCUSSIONS IN PLANT PHYSIOLOGY 1(1-0) FS
Prerequisites: BO 414 (ZO 414) or BO 421, organic chemistry

Group discussions at an advanced level of selected topics of current interest in plant physiology. Graduate Staff

BO 660 (ZO 660) ADVANCED TOPICS IN ECOLOGY I 4(3-3) S
Prerequisite: BO 560 (ZO 560)

A consideration in depth of the major fields of ecology. Subject matter will be developed through seminars and lectures based on classical and current literature, and principles will be illustrated by laboratory exercises and field trips. Topics covered include microenvironment, community ecology, ecosystems and nutrient cycling. (Offered 1971-72 and alternate years.) Mr. Cooper

BO 661 (ZO 661) ADVANCED TOPICS IN ECOLOGY II 4(3-3) S
(See zoology, page 336.)

BO 691 BOTANY SEMINAR 1(1-0) FS

Scientific articles, progress reports in research and special problems of interest to botanists are reviewed and discussed. Graduate student credit is allowed if one paper per semester is presented at the seminar. Graduate Staff

BO 693 SPECIAL PROBLEMS IN BOTANY Credits Arranged

Directed research in some specialized phase of botany other than a thesis problem but designed to provide experience and training in research. Graduate Staff

BO 699 RESEARCH Credits Arranged

Original research preliminary to writing a master's thesis or a doctoral dissertation. Graduate Staff

Cell Biology

Many present-day biologists seek a basic understanding of biological phenomena at the cellular and subcellular or molecular level. They recognize that principles and concepts developed in one system may apply to the cells of many varieties of organisms and may help to explain the complicated activities of more highly organized systems such as organs and tissues, individuals and populations. Biologists interested in this approach need a broader background than that generally provided by the customary major and minor.

North Carolina State University provides a program for this type of biologist through an interdepartmental minor in cell biology. In pursuing the cell biology program, students major in one of the many areas of biology, but select a thesis problem involving research at the cellular or subcellular level and take a combination of required and elective courses to provide an appropriate interdepartmental minor. The minor field is represented on a student's graduate committee by a cell biologist from a department other than that of his major professor.

The minimum requirements for the graduate minor in cell biology are as follows:

Master of Science

BCH 551 GENERAL BIOCHEMISTRY	3(3-0) F
BO 414 (ZO 414) CELL BIOLOGY	4(3-3) F
BS 690 SEMINAR IN CELL BIOLOGY	1(1-0) S
BS 696 TOPICS IN BIOLOGICAL ULTRASTRUCTURE	1(1-0) F

Doctor of Philosophy

BCH 561 (GN 561, MB 561) BIOCHEMICAL AND MICROBIAL GENETICS	3(3-0) F
BS 690 SEMINAR IN CELL BIOLOGY	1(1-0) S
BS 696 TOPICS IN BIOLOGICAL ULTRASTRUCTURE	1(1-0) F
ZO 614 ADVANCED CELL BIOLOGY	3(3-0) S
ZO 615 ADVANCED CELL BIOLOGY LABORATORY	1(0-3) S
ADVISED ELECTIVE	S

Elective and supporting courses appropriate for an individual student are chosen from the wide array available through the biological science departments. In addition, supplemental courses may be selected from among the many offered at the University of North Carolina at Chapel Hill and Duke University at Durham.

Communications concerning the Cell Biology Program, including inquiries from students wishing to minor in cell biology, should be sent to Biological Sciences, P. O. Box 5306, N. C. State University, Raleigh, North Carolina 27607.

Chemical Engineering

GRADUATE FACULTY

Professor James K. Ferrell, *Head*

Professors: Kenneth O. Beatty, Jr., Robin P. Gardner, Edward M. Schoenborn, John F. Seely, Henry B. Smith, Vivian T. Stannett; *Visiting Professor:* Warren L. McCabe; *Professor Emeritus:* Richard Bright; *Associate Professors:* Harold B. Hopfenberg, David B. Marsland, Donald C. Martin, Edward P. Stahel; *Assistant Professors:* Richard M. Felder, Ronald W. Rousseau

The Department of Chemical Engineering offers programs of advanced study leading to the Master of Science, Master of Chemical Engineering and Doctor of Philosophy degrees. Both formal and informal meetings between faculty and students are encouraged in order to promote a common interest in professional development and academic excellence.

Because graduate study in chemical engineering requires a rigorous background in fundamentals, as well as the development in an area of specialization, chemical engineers with advanced degrees are among those least affected by changes in government or industrial economic positions. A broad base in the fundamentals has also insured the chemical engineer of the ability to meet new problem areas as they arise. This has been most recently illustrated by the presence of chemical engineers at the forefront of the development of air and water pollution studies, biomedical engineering, biochemical engineering, etc.

Students entering graduate study in the department normally have a bachelor's degree in chemical engineering or its equivalent, but programs can be worked out to accommodate students with bachelor's degrees in applied mathematics, chemistry, physics and other branches of engineering. Entering students should have a background in undergraduate mathematics, physics and chemistry, including physical chemistry; and a background equivalent to undergraduate work in heat transfer, fluid mechanics, and mass transfer and diffusional operations. Deficiencies in any of these areas can normally be made up in one semester.

The most extensive area of research in the department is in the field of polymer science and engineering. Graduate and post doctoral efforts in this field include studies of ionic and free-radical polymerization, grafting reactions, membrane technology and design of polymerization reactors. Other active research areas include chemical reaction engineering, heat and mass transfer, process optimization and control, particulate processes, pollution abatement and control, thermodynamics and biomedical engineering. Under these general headings, current efforts include studies of the heat transfer and fluid dynamic properties of the heat pipe, contact nucleation and growth mechanisms in industrial crystallization, particle dynamics in stirred tanks, mixing effects in chemical reactors, photochemical reaction engineering, the application of the hybrid computer to problems in adaptive process modeling and control and chemical reactor stability, modeling of continuous ball mills, design and simulation of artificial organs, water purification by reverse osmosis, and the design and economics of air pollution control systems.

The proximity of UNC-Chapel Hill and Duke University, as well as the Research Triangle Park which houses a number of government and industrial research facilities, lends considerable support to many of the research programs at N. C. State. The Air Pollution Control Office, for example, has a facility in the Research

Triangle Park which provides a natural contact between government and university scientists studying air pollution problems. Similarly, biomedical and biochemical studies at State are strengthened by faculty contacts with their counterparts in these areas at UNC-Chapel Hill and Duke.

The Department of Chemical Engineering occupies 40,000 square feet in the east wing of Riddick Engineering Laboratories. There are several excellent general-purpose laboratory facilities within the building for graduate research. The department also has several other special facilities including laboratories for process control and dynamics, thermodynamics, powder science and technology, desalination and polymer research; in addition, three pilot plant systems have been built to study heat transfer, reaction kinetics and complex mixing phenomena in polymerization systems. A well equipped instrumental analysis laboratory is maintained within the department; other specialized instruments such as electron beam and scanning microscopes are available on campus should a research project require their use. The School of Engineering computer facilities are conveniently housed within the chemical engineering wing of Riddick Hall. A new terminal link to an IBM 360/75 computer located in the Research Triangle Park provides rapid service on almost all digital jobs. Additional digital capabilities are provided by an IBM 1130 computer which is interfaced to an EAI TR 48 analog computer providing an excellent hybrid facility. Finally, an excellent machine shop assures the student that almost any special equipment needed for his research can be constructed within the department.

A number of research projects within the department are supported by industry as well as state and federal agencies. Research assistantships for work on these specific projects are available and may be nine or twelve month appointments.

The department also offers teaching assistantships which carry a nine-month stipend of $2900. These are half-time appointments and usually involve assisting in the teaching of courses, supervising undergraduate laboratories or other laboratory work as the need arises. In addition, the department has several industrially sponsored fellowships which require no specific duties.

FOR ADVANCED UNDERGRADUATES

CHE 412 TRANSPORT PROCESSES II 3(3-0) S
Prerequisite: CHE 327

An intensive study of momentum, heat and mass transport processes, with emphasis on chemical engineering. Problems in fluid, heat and mass transfer.

CHE 425 PROCESS MEASUREMENT AND CONTROL I 3(2-2) F
Prerequisites: CHE 225, CHE 327

A study of the continuous control of typical chemical engineering processes including the techniques of feedback, cascade, feedforward and interacting systems. Dynamics, stability and control of heat exchangers, flow systems, distillation columns and chemical reactors are illustrated.

CHE 426 PROCESS MEASUREMENT AND CONTROL II 3(2-2) S
Prerequisite: CHE 425 or EE 435 or MAE 435

An extension of the theory and application of process control techniques to the analysis of physical systems. This course covers sampled data and nonlinear systems and includes an introduction to optimum control techniques and adaptive control.

CHE 428 SEPARATION PROCESSES II 3(3-0) S
Prerequisite: CHE 327

An intensive study of the principles (diffusion and interphase mass transfer) underlying such unit operations as distillation, drying, absorption, etc., with emphasis on procedures and economic problems.

CHE 431 CHEMICAL ENGINEERING LABORATORY I 3(1-5) S
Prerequisite: CHE 311

Laboratory work on typical apparatus involving unit operations. Experiments are designed to augment the theory and data of lecture courses and to develop proficiency in the writing of technical reports.

CHE 432 CHEMICAL ENGINEERING LABORATORY II 3(1-5) F
Prerequisite: CHE 431

A continuation of CHE 431. This course will consist of a small number of group projects in research, design or development.

CHE 446 CHEMICAL PROCESS KINETICS 3(3-0) F
Prerequisite: CHE 315

A basic study of homogeneous and heterogeneous chemical reactions, and of catalysis.

CHE 451 CHEMICAL ENGINEERING DESIGN 3(2 2) FS
Prerequisites: CHE 315, CHE 327, CHE 432

A general treatment of chemical process design and optimization. The interplay of economic and technical factors in process development, site selection, project design, construction and production management. Applications of cost accounting, cost estimation for new equipment, measures of profitability. Case studies, readings, design problems and reports.

CHE 495 SEMINAR IN CHEMICAL ENGINEERING 1(1 0) FS

Professional aspects of chemical engineering; topics of current interest in chemical engineering.

CHE 497 CHEMICAL ENGINEERING PROJECTS 1-3 FS

Introduction to research through experimental, theoretical and literature studies of chemical engineering problems. Oral and written presentation of reports.

FOR GRADUATES AND ADVANCED UNDERGRADUATES

CHE 511 PROBLEM ANALYSIS FOR CHEMICAL ENGINEERS 3(3-0) S
Prerequisites: CHE 428, MA 301

The application of the methods of mathematical analysis to the formulation and solution of problems in transport phenomena, transient phenomena in unit operations, process dynamics and thermodynamics. Study and use of analog computer solutions of these problems. Mr. Martin

CHE 513 THERMODYNAMICS I 3(3-0) F
Prerequisite: CHE 315

An intermediate course in thermodynamic principles and their application to

chemical and phase equilibria. The course is largely from a macroscopic viewpoint but consideration will be given to some aspects of the statistical viewpoint.
Mr. Beatty

CHE 515 TRANSPORT PHENOMENA 3(3 0) F
Prerequisite: CHE 327

A theoretical study of transport of momentum, energy and matter with emphasis on the latter two. The diffusional operations, including coupled heat and mass transfer, are introduced in the light of the theory. Mr. Marsland

CHE 517 KINETICS AND CATALYSIS 3(3-0) F
Prerequisite: CHE 446

An intensive study of homogeneous and heterogeneous kinetic reactions. Emphasis will be placed on fundamental approaches, experimental methods and mathematical techniques in engineering analysis of chemical reaction systems.
Mr. Felder

CHE 521 MASS TRANSFER OPERATIONS 3(3-0) S
Prerequisite: CHE 327

Multicomponent mass transfer operations will be discussed in light of recent developments and innovations in both the operations themselves and in calculational techniques used in analyzing the operations. The equilibrium stage concept will be developed and as time permits, a discussion of the continuous rate processes will be undertaken. Problems unique to given operations, such as are encountered in extractive and azeotropic distillation will be discussed during the course.
Mr. Rousseau

CHE 523 FLUID DYNAMICS AND HEAT TRANSFER 3(3 0) F
Prerequisite: CHE 311

Convective heat transfers in chemical process equipment, such as heat exchangers, chemical reactors, distillation and extraction reboilers, etc., and fluid dynamics and heat transfer of multiphase, multicomponent and chemically reactive systems. Mr. Ferrell

CHE 525 PROCESS DYNAMICS 3(3-0) F
Prerequisite: CHE 425

A detailed study of the dynamic response of typical chemical process equipment including instrumentation and process control devices. Fundamental concepts of automatic control of process variables such as temperature, pressure, flow and liquid level. Mr. Martin

CHE 527 (OR 527) OPTIMIZATION OF ENGINEERING PROCESSES 3(3-0) F
Prerequisites: MA 511, CSC 111 or equivalent

Mathematical methods for the optimization of engineering processes are developed, and illustrative applications of these methods are presented and discussed. Specific topics covered are drawn from a list which includes mathematical programming, geometric programming, sensitivity analysis, direct search and elimination techniques, variational techniques and the minimum principle, quasilinearization and dynamic programming. The emphasis throughout the course is on applications of the techniques discussed rather than fully rigorous development of the theory. Mr. Felder

CHE 535 ENGINEERING ECONOMY IN AIR POLLUTION CONTROL SYSTEMS 3(3 2) S
Prerequisites: MAE 409, CE 576, or equivalent first course

Principles and practice in designing equipment for the abatement of air pollution;

estimation of capital cost and operating expense; economic optimization under various kinds of tax laws. Mr. Marsland

CHE 541 CELLULOSE INDUSTRIES 3(3-0) F
Prerequisite: Organic chemistry

Methods of manufacture and application of cellulose chemical conversion products. Emphasis placed on recent developments in the field of synthetic fibers, film, lacquers and other cellulose compounds. Mr. Seely

CHE 543 TECHNOLOGY OF PLASTICS 3(3-0) S
Prerequisite: Organic chemistry

The properties, methods of manufacture and applications of synthetic resins. Recent developments in the field are stressed. Mr. Schoenborn

CHE 569 (TC 569) POLYMERS, SURFACTANTS AND COLLOIDAL MATERIALS 3(3-0) F
Prerequisites: CHE 315, CH 431, CH 223

A survey of the relationship between molecular structure and bulk properties of nonmetallic materials as applied in chemical engineering processes. Special attention will be directed to the application of surface and colloid chemistry as well as polymer science. Mr. Hopfenberg

CHE 597 CHEMICAL ENGINEERING PROJECTS 1-3 FS
Prerequisite: Graduate standing

A laboratory study of some phase of chemical engineering or allied field.
Graduate Staff

CHE 598 SPECIAL TOPICS IN CHEMICAL ENGINEERING 1 3 FS
Prerequisite: Graduate standing

Study and investigation of special topics in chemical engineering. The course may consist of directed reading of the literature of chemical engineering, introduction to research methodology, special topics of current interest, seminar discussions dealing with special topics, etc. Graduate Staff

FOR GRADUATES ONLY

CHE 611 CHEMICAL PROCESS DESIGN AND SIMULATION 3(3-0) S
Prerequisite: CHE 511

Application of process analysis, simulation and optimization techniques to case studies of complex chemical processes. Mr. Marsland

CHE 613 THERMODYNAMICS II 3(3-0) F
Prerequisite: CHE 513

A consideration of various thermodynamic topics of special interest to chemical engineers. The effects of high pressures and high temperatures on equilibria, relationship of thermodynamics to rate process, thermodynamics of the steady state including coupled transfer process and experimental methods in thermodynamics would be typical. Mr. Beatty

CHE 617 CHEMICAL REACTION ENGINEERING 3(3-0) S
Prerequisite: CHE 517

An advanced study of ideal and real reactor systems. The approach employed is twofold: characterization of actual systems by empirical rate expressions coupled with fundamental analysis; simulation of coupled physical and chemical processes in a reactor by solution of various types of physical models. Mr. Stahel

CHE 621 ADVANCED MASS TRANSFER 3(3-0) F

Prerequisite: CHE 515

Application of transport theory and empirical devices to the analysis, synthesis and design of mass-transfer equipment. The operations of absorption, extraction, distillation, humidification and drying will be considered. Mr. Rousseau

CHE 623 ADVANCED FLUID DYNAMICS 3(3-0) S
Prerequisite: CHE 515, CHE 523

The principles of fluid dynamics and their application to laminar and turbulent flow, flow in closed channels, flow in packed beds and porous media, particle technology, industrial rheology and two phase flow. Mr. Ferrell

CHE 624 ADVANCED HEAT TRANSFER 3(3-0) F
Prerequisites: CHE 515

An advanced course dealing primarily with heat transfer between liquids and solids, optimum operating conditions and design of equipment, conduction, heating and cooling of solids, radiant heat transmission. Mr. Beatty

CHE 669 (TC 669) DIFFUSION IN POLYMERS 2(2-0) S
Prerequisite: CHE 569 or consent of instructor

An up-to-date treatment of the theory and practice of small molecule transport in polymers as applied to the chemical, polymer, textile, coatings and natural fiber industries. Mr. Hopfenberg

CHE 671 (TC 671) SPECIAL TOPICS IN POLYMER SCIENCE 1-3 F
Prerequisite: Consent of instructor

An intensive treatment of selected topics in fiber and polymer science.
Mr. Stannett

CHE 693 ADVANCED TOPICS IN CHEMICAL ENGINEERING 1-3 FS

A study of recent developments in chemical engineering theory and practice, such as ion exchange, crystallization, mixing, molecular distillation, hydrogenation, fluorination. The topic will vary from term to term.

CHE 695 SEMINAR 1(1-0) FS

Literature investigations and reports of special topics in chemical engineering and allied fields.

CHE 699 RESEARCH Credits Arranged FS

Independent investigation of an advanced chemical engineering problem. A report of such an investigation is required as a graduate thesis.

Chemistry

GRADUATE FACULTY

Professor Z ZIMMERMAN HUGUS, JR., *Head*

Professors: HENRY A. BENT, LAWRENCE H. BOWEN, CARL L. BUMGARDNER, GEORGE O. DOAK, LEON D. FREEDMAN, SAMUEL G. LEVINE, RICHARD H. LOEPPERT, *Assistant to Head,* G. GILBERT LONG, WILLIS A. REID, PAUL P. SUTTON, RAYMOND C. WHITE; *Adjunct Professor:* MONROE E. WALL; *Affiliated Professors:* WALTER J. PETERSON, HENRY A. RUTHERFORD; *Associate Pro-*

fessors: HALBERT H. CARMICHAEL, ALONZO F. COOTS, M. KEITH DEARMOND, FORREST W. GETZEN, CHESTER E. GLEIT, FORREST C. HENTZ, JR., LOUIS A. JONES, MARION L. MILES, CHARLES G. MORELAND, WILLIAM P. TUCKER, *Director of Graduate Studies*, GEORGE H. WAHL, JR; *Assistant Professors:* JON BORDNER, THOMAS C. CAVES, KENNETH W. HANCK, ANTON F. SCHREINER, THOMAS M. WARD, DENNIS W. WERTZ

The Department of Chemistry offers programs leading to the Master of Science and Doctor of Philosophy degrees. Major fields of specialization are analytical, inorganic, organic, nuclear and physical chemistry. A wide variety of advanced courses and a broad spectrum of research topics provide excellent preparation for almost every type of the many positions open to a chemist with an advanced degree.

A student entering into graduate work in chemistry should have a bachelor's degree in chemistry or its equivalent. This includes the equivalent of one-year courses in general, organic, physical and analytical chemistry, and a semester of inorganic chemistry. At least one year of college physics and two years of mathematics, including differential equations, are necessary. Students who fail to meet these requirements may in some cases be admitted on a provisional basis.

With a large graduate faculty and favorable graduate student to faculty ratio, the chemistry department emphasizes individual attention, small classes and personal collaboration on research with faculty members. Among the variety of active research projects available for thesis work are organic and inorganic syn thesis, structure and properties of organometallic compounds and transition metal complexes, stereochemistry of natural and synthetic products, kinetics and mechanisms of reactions, radiochemistry, microanalysis, electrochemistry, quantum chemistry, and infrared, Raman, Mossbauer, nuclear magnetic resonance, nuclear quadrupole resonance and electron spin resonance spectroscopy.

The department is well equipped with standard instruments and apparatus for teaching and research. Many items of specialized equipment are available, including recording spectrophotometers covering the range from far infrared to ultraviolet, three nuclear magnetic resonance spectrometers, gas chromatographs, mass spectrometer, electron spin resonance spectrometer, circular dichroism recorder and spectropolarimeter, nuclear quadrupole resonance spectrometer, Mossbauer spectrometer and x-ray diffractometer. A complete glassblowing facility with glassblower is available for constructing special apparatus. All research activities of the department have been concentrated in a new nine-story laboratory building equipped with modern, spacious facilities and completely air-conditioned.

The department has available teaching and research assistantships, as well as a number of fellowships, for qualified applicants.

FOR ADVANCED UNDERGRADUATES

CH 401 SYSTEMATIC INORGANIC CHEMISTRY 3(3 0) S
Corequisite: CH 433

A survey of the chemical elements based on atomic structure and the periodic system, also introducing newer concepts of structure and symmetry. A knowledge of basic physical chemical principles is prerequisite.

CH 411 ANALYTICAL CHEMISTRY I 4(2-6) F
Prerequisites: CH 431, CH 434
Corequisite: CH 433

An introduction to analytical chemistry, including the design, execution and interpretation of quantitative chemical measurements. Chromatographic, gravimetric and related techniques of separation are presented.

CH 413 ANALYTICAL CHEMISTRY II 4(2-6) S
Prerequisite: CH 411

Methods of quantitative analysis based on solution chemistry, electrochemistry and the interactions of radiation with matter. Specific topics include acid-base, potentiometric and coulometric titrations, and absorption spectroscopy.

CH 428 QUALITATIVE ORGANIC ANALYSIS 3(1-6) FS
Prerequisite: CH 223

An introduction to the identification of organic compounds by means of physical properties (including infrared spectra), chemical classification tests and preparation of derivatives.

CH 431 PHYSICAL CHEMISTRY I 3(3-0) FS
Prerequisites: CH 107, MA 202, PY 207 or PY 208
Corequisite: MA 301

CH 431, CH 433 and CH 435 provide an intensive study of physical chemical principles. CH 431 emphasizes states of matter, thermodynamics, and physical and chemical equilibrium.

CH 432 PHYSICAL CHEMISTRY I LABORATORY 1(0-3) F
Corequisite: CH 431

Laboratory course to accompany the lecture work in CH 431.

CH 433 PHYSICAL CHEMISTRY II 3(3-0) FS
Prerequisites: CH 431, MA 301

A continuation of CH 431, emphasizing properties of solids and solutions, electrochemistry, reaction kinetics and kinetic theory.

CH 434 PHYSICAL CHEMISTRY II LABORATORY 2(0-6) S
Corequisite: CH 433

Laboratory projects in physical chemistry.

CH 435 PHYSICAL CHEMISTRY III 3(3-0) F
Prerequisites: CH 431, MA 301

A continuation of CH 431, emphasizing molecular structure and chemical bonding.

CH 441 COLLOID CHEMISTRY 3(2-3) S
Prerequisites: CH 220, CH 315

Adsorption; preparation, properties, constitution, stability, and application of sols, gels, emulsions, foams and aerosols; dialysis; Donnan membrane equilibrium. (Offered spring 1973 and alternate years.)

CH 461 (TC 461) CHEMISTRY OF FIBERS 3(3-0) F
(See textile chemistry, page 310.)

CH 490 CHEMICAL PREPARATIONS 3(1-6) FS
Prerequisite: Three years of chemistry

Lectures and laboratory work in preparative chemistry. Synthetic procedures will be selected to illustrate advanced methods and techniques in both inorganic and organic chemistry.

CH 491 READING IN HONORS CHEMISTRY 2-6 FS
Prerequisite: Three years of chemistry

A reading course for exceptionally able students at the senior level. The students will do extensive reading in areas of advanced chemistry and will present written reports of their findings.

CH 493 CHEMICAL LITERATURE 1(1-0) F
Prerequisite: Three years of chemistry

A systematic introduction to the location and retrieval of information required for the solution of chemical problems.

CH 499 SENIOR RESEARCH 1-3 FS
Prerequisite: Three years of chemistry

An introduction to research. Independent investigation of a research problem under the supervision of a member of the chemistry faculty.

FOR GRADUATES AND ADVANCED UNDERGRADUATES

CH 501 INORGANIC CHEMISTRY I 3(3-0) F
Prerequisite: CH 433

Modern inorganic chemistry from the point of view of the chemical bond. Chemical periodicity and its origins in atomic structure, the ionic bond and electronegativity, crystal structure and bonding in ionic solids, the metallic state, conduction and semiconductors, and the preparation and properties of illustrative compounds.

CH 503 INORGANIC CHEMISTRY II 3(3-0) S
Prerequisite: CH 501

The hydrogen molecule-ion and the theory of the covalent bond, molecular orbitals and hybridization, dipole moments and magnetic properties, the theory of acids and bases, nonaqueous solvents, coordination compounds, carbonyl and quasi-aromatic compounds, and the chemistry of the transition metals, lanthanides and actinides.

CH 511 CHEMICAL SPECTROSCOPY 3(3-0) F
Prerequisite: CH 433

Theory, analytical applications and interpretation of spectra as applied to chemical problems. Major emphasis will be placed upon ultraviolet, visible and infrared spectra.

CH 515 CHEMICAL INSTRUMENTATION 3(3-0) S
Prerequisite: CH 431
Corequisite: CH 411

Basic electronic components and circuits, the response of laboratory instruments, design and modification of typical electronic control and measurement systems. Emphasis will be placed on the transducers and control elements utilized in chemical research.

CH 521 ADVANCED ORGANIC CHEMISTRY I 3(3-0) F
Prerequisites: CH 223, CH 433 or CH 435

Structure, stereochemistry and reactions of the various classes of hydrocarbons. The molecular orbital treatment of bonding and reactivity of alkenes, the conformational interpretation of cycloalkane and cycloalkene reactivity, and the application of optical isomerism to the study of reaction mechanisms will be emphasized.

CH 523 ADVANCED ORGANIC CHEMISTRY II 3(3-0) S
Prerequisite: CH 521

An introduction to acid base theory and mechanistic organic chemistry as applied to synthetically useful organic reactions.

CH 525 PHYSICAL METHODS IN ORGANIC CHEMISTRY 3(3-0) S
Prerequisites: CH 223 and CH 433 or CH 435

Application of physical methods to the solution of structural problems in organic chemistry. Emphasis will be on spectral methods including infrared, ultraviolet, nuclear magnetic resonance, mass spectrometry, electron paramagnetic resonance, x-ray and electron diffraction, and optical rotatory dispersion.

CH 531 CHEMICAL THERMODYNAMICS 3(3-0) F
Prerequisites: CH 433, MA 301

An extension of elementary principles to the treatment of ideal and real gases, ideal solutions, electrolytic solutions, galvanic cells, surface systems and irreversible processes. An introduction to statistical thermodynamics and the estimation of thermodynamic functions from spectroscopic data.

CH 533 CHEMICAL KINETICS 3(3 0) S
Prerequisites: CH 433, MA 301

An intensive survey of the basic principles of chemical kinetics with emphasis on experimental and mathematical techniques, elements of the kinetic theory, and theory of the transition state. Applications to gas reactions, reactions in solution and mechanism studies.

CH 535 SURFACE PHENOMENA 3(3-0) S
Prerequisites: CH 433, MA 301

An intensive survey of the topics of current interest in surface phenomena. Formulations of basic theories are presented together with illustrations of their current applications. (Offered spring 1972 and alternate years.)

CH 537 QUANTUM CHEMISTRY 3(3-0) S
Prerequisites: MA 301, CH 435 or PY 407

The elements of wave mechanics applied to stationary energy states and time dependent phenomena. Applications of quantum theory to chemistry, particularly chemical bonds.

CH 545 RADIOCHEMISTRY 3(2-3) S
Prerequisite: PY 410 or CH 431

The applications of radioactivity to chemistry and the applications of chemistry to the radioactive elements, particularly the transuranium elements and fission products.

CH 562 (TC 562) PHYSICAL CHEMISTRY OF HIGH POLYMERS—BULK PROPERTIES 3(3-0) F
(See textile chemistry, page 311.)

FOR GRADUATES ONLY

CH 623 VALENCE AND THE STRUCTURE OF ORGANIC MOLECULES 3(3-0) F
Prerequisites: CH 523, CH 433

Applications of molecular orbital theory, thermodynamics and free energy relations to organic problems.

CH 625 ORGANIC REACTION MECHANISMS 3(3 0) S
Prerequisites: CH 523, CH 433

A study of the effects of structure and substituents on the direction and rates of organic reactions.

CH 627 CHEMISTRY OF METAL-ORGANIC COMPOUNDS 3(3-0) F
Prerequisite: CH 521

Preparation, properties and reactions of compounds containing the carbon metal bond, with a brief description of their uses.

CH 631 CHEMICAL THERMODYNAMICS II 3(3 0) S
Prerequisite: CH 531

Statistical interpretation of thermodynamics; use of partition functions; introduction to quantum statistics; application of statistical mechanics to chemical problems, including calculation of thermodynamic properties, equilibria and rate processes.

CH 659 (BCH 659) NATURAL PRODUCTS 3(3 0) F
Prerequisite: CH 523, CH 525 or consent of instructor

Illustrative studies of structure determination, synthesis and biosynthesis of natural substances. Modern physical methods and fundamental chemical concepts are stressed. Examples are chosen from such classes as alkaloids, terpenes, steroids and antibiotics.

CH 691 SEMINAR 1(1-0) FS
Prerequisite: Graduate standing in chemistry

Scientific articles, progress reports on research, and special problems of interest to chemists are reviewed and discussed.

CH 693 ADVANCED TOPICS IN PHYSICAL CHEMISTRY 3(3-0) FS
Prerequisites: Graduate standing and consent of instructor

An intensive treatment of selected topics of importance in current physicochemical research.

CH 695 SPECIAL TOPICS IN CHEMISTRY Maximum 3 FS
Prerequisite: Consent of department head

Critical study of special problems in one of the branches of chemistry.

CH 699 CHEMICAL RESEARCH Credits Arranged FS
Prerequisite: Graduate standing in chemistry

Special problems that will furnish material for a thesis. A maximum of six semester credits is allowed toward a master's degree; there is no limitation on credits in the doctoral program.

Civil Engineering

GRADUATE FACULTY

Professor DONALD L. DEAN, *Head*
Professor PAUL Z. ZIA, *Associate Head*
Professors: MICHAEL AMEIN, WILLARD F. BABCOCK, CHARLES R. BRAMER, PAUL D. CRIBBINS, RALPH E. FADUM, *Dean, School of Engineering*, CLINTON L. HEIMBACH, JOHN W. HORN, ABDEL-AZIZ I. KASHEF, WESLEY G. MULLEN, CHARLES SMALLWOOD, JR., MEHMET E. UYANIK, HARVEY E. WAHLS, *Graduate Administrator; Adjunct Professor:* CARROLL L. MANN, JR.; *Associate Professors:* JOHN F. ELY, WILLIAM S. GALLER, KERRY S. HAVNER, LEONARD J. LANGFELDER, JEHANGIR F. MIRZA, CHI CHAO TUNG; *Adjunct Associate Professors:* CHARLES P. FISHER, JR., SAMUEL D. SHEARER, JR.; *Assistant Professors:* NEWTON V. COLSTON, JR., WILLIAM J. HEAD, FRANK J. HUMENIK, JERRY L. MACHEMEHL, J. C. SMITH; *Environmental Engineering Extension Specialist:* DONALD R. JOHNSTON.

The Department of Civil Engineering offers programs of study leading to Master of Science, Master of Civil Engineering and Doctor of Philosophy degrees. Students may major in soil mechanics and foundation engineering, structural engineering, transportation engineering or sanitary and water resources engineering.

The basic objective of graduate study in civil engineering is to provide the student the knowledge and skills essential to a successful career in a variety of activities such as teaching, research, development and advanced design. In addition to the formal course work, the student is brought into close contact with the graduate faculty through participation in research projects.

The department is actively engaged in a broad area of research in which a student may undertake his thesis work. The current research activities of the department include investigations in structural theories, both deterministic and probabilistic; continuum and discrete field mechanics; limit analysis and design in metal and in structural concrete; structural models; structural dynamics; plate and shell theory and design; soil dynamics; fundamental behavior of soils; highway safety; traffic flow theory; land use and urban planning; hydraulics and hydrology; waste disposal and pollution control. Many of these investigations are sponsored by industries, federal and state agencies including the continuing North Carolina Cooperative Highway Research Program.

The department is housed in an attractive and functional air-conditioned building with adequate office and laboratory spaces assigned to graduate students for study and research. The various laboratories of the department are well equipped with both standard and specialized instruments and apparatus for research and teaching. In addition, there are several unusual facilities including a large uni versal structural test floor; a dual channel closed-loop structural testing system for static and dynamic loading; a Hele Shaw apparatus for study of salt water intrusion; facilities for chemical and biological research; a wave generator for research in coastal wave motion; time-lapse photographic equipment for traffic studies; facilities for airphoto interpretation and photogrammetry; a resonant column apparatus used in conjunction with the triaxial equipment for the study of dynamic properties of soils; gyratory equipment for the study of compaction of soils and bituminous materials; a small test track for studying wear and polishing of pavement aggregates and for repetitive loading of pavement samples; facilities for aggregate soundness tests; miniature precision sand blast device for solid

particle impingement erosion study; and ultrasonic non-destructive testing equip ment.

The department cooperates with other divisions of the University in a number of joint programs. Qualified students may schedule their courses in this department and in the Department of City and Regional Planning at the University of North Carolina at Chapel Hill to receive a dual degree in Master of Science with major in transportation engineering and Master of Regional Planning. Multidisciplinary study and research programs are also available through the North Carolina High way Safety Research Institute, Water Resources Research Institute and the Coastal Research Program. The department is also engaged in the interdisciplinary research programs in mechanics and materials as the result of a National Science Foundation Science Development Program grant.

Students in other disciplines also find opportunities for developing minor areas of study within the framework of course offerings of the department. In particular, courses of instruction in stream sanitation and industrial waste disposal provide the types of training in pollution control often in great demand by industry.

A brochure and supplementary information, describing in greater detail the opportunities for graduate study and research as well as assistantships and fellowships in the Department of Civil Engineering, are available upon request from the head of the department.

FOR ADVANCED UNDERGRADUATES

CE 406 TRANSPORTATION ENGINEERING II 3(2 2) F
Prerequisite: CE 305

An extension of Transportation Engineering I with particular emphasis on urban transportation problems and the actual design of modal interfaces such as airports, shopping centers, parking garages, port facilities and other multimodal terminals.

CE 422 STRUCTURAL DESIGN IIA 3(2 3) S
Prerequisites: CE 332, CE 421, CE 425

Principles of design and analysis of reinforced concrete members with emphasis on the ultimate strength theory. Application of the principles in a design project of a reinforced concrete structure. (Not available after spring 1973.)

CE 427 STRUCTURAL ENGINEERING II 3(2-3) F
Prerequisite: CE 326

Basic concepts of structural design. Criteria for safety and serviceability. Structural connections. Analysis and design of complete structural systems.

CE 443 SOIL ENGINEERING II 3(3-0) F
Prerequisite: CE 342

Lateral earth pressure theories and their application to analysis and design of slopes and retaining structures; ground water hydraulics; placement of fills; soil behavior in pavement systems, stabilization techniques.

CE 450 CIVIL ENGINEERING DESIGN 3(1-6) S
Prerequisite: One from CE 406, CE 427, CE 443 or CE 484

An integrated team approach is used to a major civil engineering project involving planning, design and analysis under realistic conditions including consideration of environmental factors. (Not available until spring 1973.)

CE 460 CONSTRUCTION ENGINEERING PROJECT 3(2-3) S
Prerequisites: CE 463, CE 466

A study of the planning, design, construction and management of a construction project. (Not available until spring 1973.)

CE 463 COST ANALYSIS AND CONTROL 3(2-3) F
Prerequisite: CE 365

Principles of cost engineering, project estimating, bid procedures, construction cost analysis and control.

CE 464 LEGAL ASPECTS OF CONTRACTING 3(3-0) S
Prerequisite: Senior standing

Legal aspects of construction contract documents and specifications; owner-engineer contractor relationships and responsibilities; bids and contract performance; labor laws.

CE 466 CONSTRUCTION ENGINEERING II 3(2-3) F
Prerequisites: CE 326, CE 365

An introduction to construction of building systems, with emphasis on the planning, analysis, design and construction of structural subsystems.

CE 472 ELEMENTS OF AIR QUALITY MANAGEMENT 3(2-3) S
Prerequisite: College level physics and senior standing

Air pollution is studied from the standpoint of community air quality management. Topics to be discussed include: pollutant sources; effects on biological systems, materials and the atmosphere; meteorological factors; air sampling; abatement and control techniques; air quality and emission standards; and legal, economic and administrative aspects. Mr. Johnston

CE 484 WATER RESOURCES ENGINEERING II 3(3-0) F
Prerequisite: CE 383

The study of the occurrence, flow and control of natural and impounded waters. Case studies of storm drainage, flood control and stream sanitation are utilized to illustrate the use of these principles in the management of river basin water resources.

CE 487 (OY 487, MAS 487) PHYSICAL OCEANOGRAPHY 3(3-0) S
(See physical oceanography, page 248.)

CE 498 SPECIAL PROBLEMS IN CIVIL ENGINEERING 1-3 FS
Prerequisite: Senior standing in CE or CEC

Study and investigation of special problems in some phase of civil engineering. The course may consist of directed reading in the literature of civil engineering, introduction to research methodology, seminar discussions dealing with special civil engineering topics of current interest.

FOR GRADUATES AND ADVANCED UNDERGRADUATES

CE 507 AIRPHOTO ANALYSIS I 3(2-3) FS
Prerequisite: Senior standing

Principles and concepts for engineering evaluation of aerial photographs, including analysis of soils and surface drainage characteristics. Mr. Wahls

CE 508 AIRPHOTO ANALYSIS II 3(2 3) S
Prerequisite: CE 507

Continuation of CE 507 with applications to highway and airport projects.
Mr. Wahls

CE 509 PHOTOGRAMMETRY 3(2-3) F
Prerequisite: CE 201 or CE 301

Elements of aerial photogrammetry as applied to civil engineering, surveying and mapping, geometry of aerial photographs, flight planning for aerial photography and stereoscopic plotter instruments, especially the Kelsh Plotter. Staff

CE 514 MUNICIPAL ENGINEERING PROJECTS 3(2-3) S
Prerequisite: Senior standing in civil engineering

Special problems relating to public works, public utilities, urban planning and city engineering. Messrs. Babcock, Horn

CE 515 TRANSPORTATION OPERATIONS 3(3 0) F
Prerequisite: CE 406

The analysis of traffic and transportation engineering operations.
Messrs. Heimbach, Horn

CE 516 TRANSPORTATION DESIGN 3(2 3) S
Prerequisite: CE 406

The geometric elements of traffic and transportation engineering design.
Messrs. Cribbins, Horn

CE 517 WATER TRANSPORTATION 3(3 0) F
Prerequisite: CE 305

The planning, design, construction and operation of waterways, ports, harbors and related facilities. Development of analytical techniques for evaluating the feasibility of piers, ports and multipurpose river basin projects. The design of marine structures and civil works that are significant in civil engineering, including locks, dams, harbors, ports, and contractive and protective works.
Mr. Cribbins

CE 524 ANALYSIS AND DESIGN OF MASONRY STRUCTURES 3(3-0) F
Prerequisite: CE 326

Theory and design of masonry arches, culverts, dams, foundations and masonry walls subjected to lateral loads. Messrs. Bramer, Mirza

CE 525, 526 ADVANCED STRUCTURAL ANALYSIS I, II 3(3-0) FS
Prerequisite: CE 326

A study in depth of classical structural theories, including generalized stiffness and flexibility methods. Treatment of secondary stresses and highrise structures.
Messrs. Dean, Smith

CE 527 NUMERICAL METHODS IN STRUCTURAL ANALYSIS 3(3-0) F
Corequisite: CE 525

Numerical solution of problems in structural mechanics, including matrix operations, relaxation, iteration, numerical integration, finite differences and finite element methods. Messrs. Havner, Smith

CE 531 EXPERIMENTAL STRESS ANALYSIS 3(2 3) F
Prerequisite: CE 427

Theoretical and experimental techniques for the analysis of strain and stress including mechanical and electrical strain gages, brittle coating, grid method and an introduction to photoelasticity. Structural analysis by indirect and direct models. Messrs. Bramer, Mirza, Zia

CE 534 PLASTIC ANALYSIS AND DESIGN 3(3 0) S
Prerequisite: CE 427

Theory of plastic behavior of steel structures; concept of design for ultimate load and the use of load factors. Analysis and design of components of steel frames including bracings and connections. Mr. Bramer

CE 536 THEORY AND DESIGN OF PRESTRESSED CONCRETE 3(3-0) F
Corequisite: CE 427

The principles and concepts of design in prestressed concrete including elastic and ultimate strength analyses for flexural, shear, bond and deflection. Principles of concordancy and linear transformation for indeterminate prestressed structures. Application of prestressing to tanks and shells. Messrs. Mirza, Zia

CE 541 (MAS 541, OY 541) GRAVITY WAVE THEORY I 3(3-0) S
(See physical oceanography, page 249.)

CE 544 FOUNDATION ENGINEERING 3(3-0) S
Prerequisite: CE 342

Subsoil investigations; excavations; design of sheeting and bracing systems; control of water; footing, grillage and pile foundations; caisson and cofferdam methods of construction. Messrs. Kashef, Langfelder

CE 547 FUNDAMENTALS OF SOIL MECHANICS 3(3-0) FS
Prerequisite: EM 301

Physical and mechanical properties of soils governing their use for engineering purposes; stress relations and applications to a variety of fundamental problems. Mr. Wahls

CE 548 ENGINEERING PROPERTIES OF SOILS I 3(2-3) F
Prerequisite: CE 342

The study of soil properties that are significant in earthwork engineering, including properties of soil solids, basic physiochemical concepts, classification, identification, plasticity, permeability, capillarity and stabilization. Laboratory work includes classification, permeability and compaction tests. Messrs. Kashef, Langfelder

CE 549 ENGINEERING PROPERTIES OF SOILS II 3(2-3) S
Prerequisite: CE 548

Continuation of CE 548, including the study of compressibility, stress-strain relations and shear strength theories for soil. Laboratory work includes consolidation and shear strength tests. Mr. Langfelder

CE 551 THEORY OF CONCRETE MIXTURES 3(3-0) F
Prerequisite: CE 332

Course work consists of study in depth of the theory of portland cement concrete mixtures including technology development and published research. Study includes types and properties of portland and special cements including chemical

reactions; brief examination of history of mixture design; detailed study of current design methods including water cement ratio, fineness modulus, B/Bo, American Concrete Institute and Portland Cement Association procedures; properties of fresh and hardened concretes; strength-age curing relationships, durability; admixtures; special concretes; production; and quality control.
Mr. Mullen

CE 553 ASPHALT AND BITUMINOUS MATERIALS 3(2-3) F
Prerequisite: CE 332

Course work consists of study in depth of properties of asphalts and tars for use in waterproofing and bituminous materials and study of the theories of design of bituminous mixtures for construction and paving uses. Study includes types and properties of asphalt cements, cutbacks, emulsions, blown asphalts and tars; brief examination of historical developments; detailed study of bituminous mixture design; properties of bituminous mixtures; and current research. Laboratory work includes standard tests on asphalts, tars and road oils; design, manufacture and testing of trial batches; and current research techniques. Messrs. Head, Mullen

CE 555 HIGHWAY AND AIRPORT PAVEMENT DESIGN 3(2 3) S
Prerequisite: CE 406 or CE 443

Theoretical analysis and design of highway and airport pavements with critical evaluation of current design practices. Mr. Head

CE 570 (BAE 570, MB 570) SANITARY MICROBIOLOGY 3(2-3) S
Prerequisite: MB 401 or equivalent

Fundamental aspects of microbiology and biochemistry are presented and related to problems of stream pollution, refuse disposal and biological treatment. Laboratory exercises present basic microbiological techniques and illustrate from a chemical viewpoint some of the basic microbial aspects of waste disposal.
Mr. Humenik

CE 571 THEORY OF WATER AND WASTE TREATMENT 3(3-0) F
Prerequisite: Graduate standing

Study of the physical, chemical and biological principles underlying water and waste treatment processes, including diffusion of gases, solubility, equilibrium and ionization, aerobic and anaerobic stabilization processes, sludge conditioning and disposal. Mr. Galler

CE 572 UNIT OPERATIONS AND PROCESSES IN WASTES ENGINEERING 3(1 6) S
Prerequisite: CE 571

Processes and operations in wastes engineering, including sedimentation, coagulation, filtration, adsorption, biological treatments, softening and new developments. Messrs. Colston, Smallwood

CE 573 ANALYSIS OF WATER AND WASTES 3(1 6) F
Corequisite: CE 571

Chemical and physical analysis of water and wastes and interpretation of results. Messrs. Colston, Galler

CE 574 RADIOACTIVE WASTE DISPOSAL 3(2-3) FS
Prerequisite: PY 407

Unit operations and processes employed in treatment and disposal of radioactive wastes. Mr. Smallwood

CE 575 CIVIL ENGINEERING SYSTEMS 3(3-0) S
Prerequisite: MA 405

An examination of civil engineering systems and their design optimization. The systems to be studied include water resources engineering, structural engineering, transportation engineering and construction. Mr. Galler

CE 576 ATMOSPHERIC POLLUTION 3(3-0) S
Prerequisite: Graduate or advanced undergraduate standing

A survey of the problem of atmospheric pollution. Topics to be discussed include: pollutant sources; effects on man and other animals, vegetation, materials and visibility; meteorological factors; air sampling; control devices; air quality and emission standards; and legal economic and administrative aspects. Mr. Johnston

CE 578 (BAE 578) AGRICULTURAL WASTE MANAGEMENT 3(2-3) F
(See biological and agricultural engineering, page 77.)

CE 580 FLOW IN OPEN CHANNELS 3(3-0) FS
Prerequisite: CE 382

The theory and applications of flow in open channels, including dimensional analysis, momentum-energy principle, gradually varied flow, high-velocity flow, energy dissipators, spillways, waves, channel transitions and model studies.
Mr. Amein

CE 581 (MAS 581) INTRODUCTION TO OCEANOGRAPHIC ENGINEERING 3(3-0) F
Prerequisite: CE 382

A rigorous treatment of the engineering aspects of physical oceanography. The theory for the propagation of waves, methods of wave forecasting and the analysis of wave spectra are presented. The applications of physical oceanography to the design of marine and coastal installations are shown. Messrs. Amein, Machemehl

CE 591, 592 CIVIL ENGINEERING SEMINAR 1(1 0) FS

Discussions and reports of subjects in civil engineering and allied fields.
Graduate Staff

CE 598 CIVIL ENGINEERING PROJECTS 1-6 FS

Special projects in some phase of civil engineering. Graduate Staff

FOR GRADUATES ONLY

CE 601 TRANSPORTATION PLANNING 3(3-0) S
Prerequisite: CE 515

The planning, administration, economics and financing of various transportation engineering facilities. Mr. Cribbins

CE 602 ADVANCED TRANSPORTATION DESIGN 3(2-3) F
Prerequisite: CE 516

Design of major traffic and transportation engineering projects.
Mr. Heimbach

CE 603 AIRPORT PLANNING AND DESIGN 3(2 3) F
Corequisite: CE 515

The analysis, planning and design of air transportation facilities.
Messrs. Heimbach, Horn

CE 604 URBAN TRANSPORTATION PLANNING 3(3 0) S
Prerequisite: CE 515

Planning and design of urban transportation systems as related to comprehen sive urban planning; principles of land use planning, urban thoroughfare planning and regional planning. Messrs. Heimbach, Horn

CE 605 TRAFFIC FLOW THEORY 3(3 0) F
Prerequisites: CE 515, ST 515

The theoretical techniques used to describe vehicular traffic movement on a street or highway network, including the use of differential-difference equations, hydrodynamic models, probabilistic models, and computer simulation.
Mr. Heimbach

CE 623 THEORY AND DESIGN OF ARCHES 3(3 0) F
Prerequisites: CE 427, CE 526

Elastic theory of single- and multi span arches with various boundary conditions. Development of design criteria for steel and concrete arches. Mr. Uyanik

CE 624 ANALYSIS AND DESIGN OF STRUCTURAL SHELLS AND FOLDED PLATES 3(3-0) S
Prerequisites: CE 525, EM 511

Treatment of roof structures in the form of folded and curved surfaces. Membrane and bending stress analysis of folded plates, shells of revolution, cylindrical and conical shells and free form systems. Numerical and closed form solutions. Design criteria for concrete and metallic structures.
Messrs. Dean, Havner, Uyanik

CE 625, 626 ADVANCED STRUCTURAL DESIGN I, II 3(2-3) FS
Prerequisite: CE 427
Corequisites: CE 525, CE 526

Complete structural design of a variety of projects including comparative study of alternative structural systems, synthesis and optimization. Mr. Uyanik

CE 627 DESIGN OF STRUCTURES FOR DYNAMIC LOADS 3(3 0) S
Prerequisites: CE 526, EM 555

The study of response of structures and structural elements subjected to dynamic loadings such as wind, earthquake and blast. Critical examination of design criteria for earthquake and blast-resistant structures. Mr. Tung

CE 631 FIELD ANALYSIS OF STRUCTURAL SYSTEMS 3(3-0) F
Prerequisite: CE 525

Primarily an exposition of the techniques of discrete field mechanics for the analysis of structures. Emphasis is on the closed-form analysis of regular structural lattices or nets and ribbed or reinforced continuous systems. Additional topics include: a cursory study of special continuous field solutions; and open form solutions for irregular systems. Mr. Dean

CE 635 ADVANCED THEORY OF CONCRETE STRUCTURES 3(3-0) S
Prerequisite: CE 536

Inelastic theory of structural concrete members under flexure, axial load, combined flexure and axial compression, shear and torsion. Yield line theory of slabs. Limit analysis of beams and frames of reinforced and prestressed concrete. Behavior and strength of structural concrete members under dynamic loading.
Mr. Zia

CE 641, 642 ADVANCED SOIL MECHANICS 3(3-0) FS
Prerequisite: Graduate standing

Theories of soil mechanics; failure conditions; mechanical interaction between solids and water, and problems in elasticity and plasticity pertaining to earth work engineering. Mr. Wahls

CE 643 HYDRAULICS OF GROUND WATER 3(3 0) FS
Prerequisite: Graduate standing

Principles of ground water hydraulics; theory of flow through idealized porous media; the flow net solution; seepage and well problems. Mr. Kashef

CE 644 GROUND WATER ENGINEERING 3(3-0) F
Prerequisite: CE 643 or equivalent

Ground water problems as related to engineering works, ground water circulation and inventories, subsidence of the ground and its evaluation due to pumping, method of images applied to water circulation of wastes and salt water encroachment in coastal aquifers, transient flow systems in wells and earth dams and embankments. Leakage problems, practical ground water problems and their analysis by computers and electrical models. The legal aspects of ground water conservation and the implied technical and engineering phases. Mr. Kashef

CE 646 DYNAMICS OF SOILS AND FOUNDATIONS 3(3-0) F
Prerequisite: CE 641

The application of vibration and wave propagation theories to soil media, the review of existing experimental data and empirical procedures for analysis of foundation vibrations, the prediction of soil responses to impulse loads, dynamic properties of soils and methods for their determination, design procedures for foundations subjected to dynamic forces. Mr. Wahls

CE 651 THEORY OF LIMIT ANALYSIS 3(3-0) F
Prerequisites: CE 526 or EM 551

General theorems of limit analysis and shakedown in elastic-plastic structures. Applications to frames (cyclic loading), grids, arches, plates and shells. Introduction to plastic instability and impact loading. Mr. Havner

CE 652 INELASTIC SOLIDS AND STRUCTURES 3(3-0) S
Prerequisites: EM 503 or EM 501 and MA 405 or equivalent

Mechanisms of slip in metals, Schmid's law; general theories of a polycrystalline aggregate. Phenomenological yield and hardening laws; comparisons with experiment. Extremum principles and formulation of boundary value problems; numerical methods of plastic strain analysis in two and three dimensions. Introduction to finite deformation theory. Mr. Havner

CE 671 ADVANCED WATER SUPPLY AND WASTE WATER DISPOSAL 4(3-3) F
Prerequisite: CE 484

Problems relating to water supply and waste collection. Mr. Smallwood

CE 672 ADVANCED WATER AND WASTES TREATMENT 4(3-3) S
Prerequisite: CE 484

Problems relating to the treatment of water and wastes. Mr. Smallwood

CE 673 INDUSTRIAL WATER SUPPLY AND WASTE DISPOSAL 3(3-0) FS
Corequisite: CE 571

Water requirements of industry and the disposal of industrial wastes. Mr. Galler

CE 674 STREAM SANITATION 3(3-0) FS
Corequisite: CE 571

Biological, chemical and hydrological factors that affect stream sanitation and stream use. Messrs. Galler, Smallwood

CE 698 SPECIAL TOPICS IN CIVIL ENGINEERING 1-3 FS
Prerequisite: Graduate standing

The study of special advanced topics of particular interest in various areas of civil engineering. Graduate Staff

CE 699 CIVIL ENGINEERING RESEARCH Credits Arranged FS

Independent investigation of an advanced civil engineering problem; a report of such an investigation is required as a graduate thesis. Graduate Staff

Computer Science

GRADUATE FACULTY

Professor PAUL E. LEWIS, *Head*
Professor: LEROY B. MARTIN, *Director of the Computing Center and Assistant to the Provost for University Computing; Associate Professors:* DAVID A. LINK, YALE N. PATT; *Assistant Professors:* STYLIANOS D. DANIELOPOULOS, ROBERT J. FORNARO, JAMES W. HANSON, THOMAS L. HONEYCUTT, ALAN L. THARP

An understanding of computers and the ability to employ them effectively is essential in all scientific disciplines. Indeed, research in any academic area is frequently facilitated by the use of computers. The Department of Computer Science, therefore, offers a minor program for graduate students majoring in any other field.

A student wishing to minor in computer science should have a knowledge of a programming language as a prerequisite and should anticipate a research project involving computers as an integral part. At the master's level, three courses at the 400 level or above are required, and the student is encouraged that at least one be at the 500 level or above. The student's advisory committee, which should include at least one member from the computer science department, will assist in selecting a meaningful sequence of courses. At the Ph.D. level, the requirements are the same, except that there are no specific course requirements. It is expected, however, that a Ph.D. minor student will achieve a high level of proficiency in at least one of the following five areas of computer science:

Artificial Intelligence
Computer Organization
Numerical Analysis
Programming Languages (including compiler design)
Operating Systems

The Operations Research Committee and the Department of Computer Science have established a cooperative program leading to a master's degree in operations research with a major emphasis in computer science. The requirements for the Master of Science degree in operations research, which include a thesis, are sat-

isfied in such a way that a strong emphasis is placed on computer science in both course and research work.

Students admitted to this cooperative program are expected to satisfy all requirements for admission to the Graduate School and, in addition, to have a strong background in mathematics, statistics and the physical sciences, and a working knowledge of a versatile, higher-level programming language, such as ALGOL or PL/1. Those students who do not have the necessary background will be required to take courses eliminating the deficiencies in addition to a normal program of study. A few research and teaching assistantships are available to qualified applicants from the cooperative program each year.

Additional information regarding the cooperative program may be obtained by writing: Operations Research Committee, P. O. Box 5511, Raleigh, North Carolina 27607, or Computer Science Department, P. O. Box 5972, Raleigh, North Carolina 27607.

FOR ADVANCED UNDERGRADUATES

CSC 411 INTRODUCTION TO SIMULATION 3(3-0) F
Prerequisite: MA 312 and ST 371 or equivalent

This course is designed to introduce simulation concepts and methodology to computer science students and students from other curricula. Modeling and computational techniques, Monte Carlo methods and interactive simulation are discussed. Applications from the areas of interest of the students are used to illustrate the concepts presented in the lectures.

CSC 412 INTRODUCTION TO COMPUTABILITY, LANGUAGE AND AUTOMATA 3(3-0) S
Prerequisite: CSC 311

Sequential machines as abstractions of digital computers described by state transition graph. Sequential machines as language acceptors and as the finite control of a Turing machine. Chomsky classification of languages and machines. Universal Turing machines and the halting problem. Church's thesis. Recursive functions. Discussion with heuristic argument that a function is recursive if and only if it is Turing computable. Discussion of the semi group word problem and tree searching algorithm. Applications to artificial intelligence, perceptron simulation, game playing, syntactic analysis algorithms.

CSC 421 COMPUTER SYSTEMS FOR MANAGEMENT 3(3-0) F
Prerequisite: CSC 311

An introduction to the principles and techniques of systems design, integration and implementation related to the development of large scale management information structures. Decision criteria in the adaptation of a management system to existing or proposed computer configurations. Updating and support of the systems management function. Model building. Planning and forecasting.

CSC 431 INFORMATION RETRIEVAL 3(3-0) F
Prerequisite: CSC 311

Structure of semi-formal languages and models for the representation of structured information. The analysis of information content by statistical, syntactic and logical methods. Search and matching techniques. Automatic retrieval systems, question answering systems. Production of secondary outputs. Evaluation of retrieval effectiveness. Programming exercises applying techniques discussed in lecture will be assigned.

CSC 432 INTRODUCTION TO DIGITAL SIGNAL PROCESSING 3(2-2) S
Prerequisites: CSC 302, ST 371 and MA 231 or MA 405

This course is an introduction to the use of digital computers in the acquisition and analysis of data. Laboratory work will include hands-on computer experience. The methods developed will apply to both the biological and physical sciences.

CSC 495 SPECIAL TOPICS 1-6 FS
Prerequisite: Consent of instructor

This course is designed to serve needs not covered by existing courses. It will consist of one or more of the following types of study: reading in the literature of computer science, introductory research projects, major computer programming projects, seminars or new course development. Work may be done in any area of computer science such as software, hardware utilitization, programming languages, numerical methods or telecommunications.

FOR GRADUATES AND ADVANCED UNDERGRADUATES

CSC 501 DESIGN OF SYSTEMS PROGRAMS 3(3-0) F
Prerequisites: CSC 301, CSC 311, CSC 312

Review of batch process systems programs, their components, operating characteristics, user services and their limitations. Implementation techniques for parallel processing of input-output and interrupt handling. Overall structure of multiprogramming systems on multiprocessor hardware configurations. Details on addressing techniques, core management, file system design and management, system accounting and other user-related services. Traffic control, interprocess communication, design of system modules and interfaces. System updating, documentation and operation.

CSC 502 COMPUTATIONAL LINGUISTICS 3(3 0) F
Prerequisite: Consent of instructor

Use of a symbol manipulation language (SNOBOL 4) in solving nonnumeric problems. Study of generative grammars, including finite state, context free, context sensitive and transformational grammars. Syntactic analysis by computers: algorithms and existing analysis systems for English. Computational semantics. Information retrieval and question answering systems. This course is open to computer science students and those in other fields.

CSC 504 APPLICATION OF LINGUISTIC TECHNIQUES TO COMPUTER PROBLEMS 3(3 0) S
Prerequisite: CSC 502

Characterization of various programming languages according to the theory of transformational grammar. Automatic translations between these languages. Design of a formal language for semantics. Iconography. Design of a language for movements of artificial speech organs; automatic translation from phonemic transcriptions to expressions in such a language.

CSC 511 ARTIFICIAL INTELLIGENCE 3(3 0) F
Prerequisite: CSC 311

Definition of heuristic versus algorithmic methods, rationale of heuristic approach, description of cognitive processes. Objectives of work in artificial intelligence, simulation of cognitive behavior. Heuristic programming techniques. Survey of examples from representative application areas. The mind-brain problem and the nature of intelligence. Individual projects to illustrate basic concepts.

CSC 512 METAPROGRAMS 3(3-0) S
Prerequisite: CSC 312 or consent of instructor

The following course is intended to provide a detailed understanding of the techniques used in the design and implementation of compilers. Review of program language structures, translation, loading, execution and storage allocation. Compilation of simple expressions and statements. Organization of a compiler including compile time and run time symbol tables, lexical scan object code generation, error diagnostics, object code optimization techniques and overall design.

CSC 522 FORMAL LANGUAGES AND SYNTACTIC ANALYSIS 3(3 0) F
Prerequisites: CSC 211, CSC 311, CSC 512 (recommended)

Definition of formal grammars. Arithmetic expressions and precedence gram mars, context free and finite state grammars. Algorithms for syntactic analysis: recognizers, backtracking, operator precedence techniques. Semantics of grammatical constructs: Floyd productions, simple syntactical compilation. Relationship between formal languages and automata.

CSC 527 (MA 527) NUMERICAL ANALYSIS I 3(3-0) FS
Prerequisites: CSC 101 or CSC 111; MA 301 or MA 312; MA 231 or MA 405

Theory of interpolation, numerical integration, iterative solution of nonlinear equations, numerical integration of ordinary differential equations, matrix inversion and solution of simultaneous linear equations.

CSC 528 (MA 528) NUMERICAL ANALYSIS II 3(3 0) FS
Prerequisite: CSC 527

Least squares data approximation, expansions in terms of orthogonal functions, Gaussian quadrature, economization of series, minimax approximations, Pade approximations, eigenvalues of matrices.

CSC 532 ARTIFICIAL INTELLIGENCE II 3(3-0) S
Prerequisites: CSC 511, course in mathematical logic

A rigorous approach to artificial intelligence emphasizing pattern recognition, theorem proving, game playing, learning and heuristic programming. Students will be assigned computer projects illustrating theoretical concepts introduced in lectures.

CSC 595 SPECIAL TOPICS 1-6 FS
Prerequisite: Consent of instructor

Topics of current interest in computer science not covered in existing courses.

FOR GRADUATES ONLY

CSC 603 COMPUTATIONAL SEMANTICS 3(3-0) F
Prerequisites: CSC 502, course in mathematical logic

Theoretical prerequisites and computational techniques for the mechanical interpretation of artificial and natural language sentences. Semantics of formal languages. Structural representations of meaning. Semantics of natural languages.

Crop Science

GRADUATE FACULTY

Professor PAUL H. HARVEY, *Head*
Professors: DOUGLAS S. CHAMBLEE, WILLIAM K. COLLINS, DONALD A. EMERY, DAN U. GERSTEL, WALTON C. GREGORY, HARRY D. GROSS, GUY L. JONES,

KENNETH R. KELLER, WILLIAM L. LEWIS, THURSTON J. MANN, PHILIP A. MILLER, ROBERT P. MOORE, LYLE L. PHILLIPS, THOMAS J. SHEETS, DAVID H. TIMOTHY, JEROME B. WEBER, JOSEPH A. WEYBREW, ARCH D. WORSHAM; *Extension Professor:* CARL T. BLAKE; *Professors USDA:* CHARLES A. BRIM, JAMES F. CHAPLIN, WILL A. COPE, JOSHUA A. LEE, DONALD E. MORELAND, DONALD L. THOMPSON; *Professor Emeritus:* GORDON K. MIDDLETON; *Associate Professors:* WILLIAM T. FIKE, WILLIAM B. GILBERT, CHARLES F. MURPHY, EDWARD C. SISLER, EARL A. WERNSMAN; *Associate Professors USDA:* JOSEPH C. BURNS, THADDEUS H. BUSBICE, GEORGE R. GWYNN; *Assistant Professors:* FREDERICK T. CORBIN, RAYMOND C. LONG, ROBERT P. PATTERSON, JOHN W. SCHRADER; *Extension Assistant Professors:* JOHN G. CLAPP, JR., HAROLD D. COBLE; *Assistant Professor USDA:* CECIL F. TESTER

The Department of Crop Science offers instruction leading to the Master of Science and Doctor of Philosophy degrees in the fields of plant breeding, crop production and physiology, forage crops ecology, weed control and plant chemistry. A professional master's degree in agronomy is offered with the cooperation of the Department of Soil Science and emphasizes a unified systems approach in applying crop and soil management technology. For students who wish general training, the Master of Agriculture degree is offered.

Excellent facilities for graduate training are available. Each student is assigned office and laboratory space. Many special facilities such as preparation rooms for plant and soil samples, cold storage facilities for plant material, air conditioned rooms for studying the physical properties of cotton fiber and tobacco leaf, and growth control chambers are provided for projects which require these facilities. Greenhouse space, growth control chambers and access to the plant environment laboratories (Phytotron) are provided for projects which require these facilities. Sixteen farms are owned and operated by the state for research investigations. Research farms are located throughout North Carolina, and include a wide variety of soil and climatic conditions needed for experiments in plant breeding, crop management, forage ecology and weed control.

Strong supporting departments greatly increase opportunities for broad and thorough training. Included among those departments in which graduate students in crop science work cooperatively or obtain instruction are botany, chemistry, entomology, genetics, horticultural science, mathematics, plant pathology, soil science and statistics.

In North Carolina, a state which derives 80 percent of its agricultural income from farm crops, the opportunities for the well trained agronomist are exceedingly great. Recipients of advanced degrees in crop science at North Carolina State University are found in positions of leadership in research and education throughout the nation and the world.

FOR ADVANCED UNDERGRADUATES

CS 402 (BO 402) ECONOMIC BOTANY 3(2 3) S
Prerequisite: BO 200

Emphasis is on plants and human affairs, rather than taxonomy, production or economics. Discussions center on all phases of the inter relationships of the plant world and the life history of incipient to modern human cultures. Treatment includes plants and plant products, beneficial and harmful, that man has used as necessities of life, as ameliorants contributing to his well being, and as raw materials for industry. Ornamentals are excluded.

CS 411 ENVIRONMENTAL ASPECTS OF CROP PRODUCTION 2(2-0) F
Prerequisite: BO 421

A study of the productivity and quality of crops in relation to all environmental factors, including man, with emphasis on disorders caused by physical and biotic environmental stresses, the role of these environmental factors in normal crop development, and the utilization and manipulation of the environment for continued crop improvement.

CS 413 PLANT BREEDING 2(2 0) S
Prerequisite: GN 411

An appreciation course in plant breeding. Discussion topics include reproductive systems of higher plants; the evolution and utilization of natural and induced genetic variability; the development of appropriate selection and breeding methods; and the distribution and maintenance of improved varieties.

CS 414 WEED SCIENCE 3(2-2) F
Prerequisite: CH 220 or equivalent

Principles involved in cultural and chemical weed control. Discussions on chemistry of herbicides and the effects of the chemicals on the plant. Identification of common weeds and their seeds is given.

CS 490 SENIOR SEMINAR 1(0-1) S
Prerequisite: Senior standing

The collection, organization, written preparation and oral delivery of scientific information concerning topics of interest in crop science.

FOR GRADUATES AND ADVANCED UNDERGRADUATES

CS 511 TOBACCO TECHNOLOGY 2(2-0) S
Prerequisites: CS 311, BO 421 or equivalent

A study of special problems concerned with the tobacco crop. The latest research problems and findings dealing with this important cash crop will be discussed. Mr. Collins

CS 513 PHYSIOLOGICAL ASPECTS OF CROP PRODUCTION 3(3 0) S
Prerequisite: BO 421

Discussion will emphasize pertinent physiological processes associated with crops and crop management such as plant growth, maturation, respiration and photoperiodism. Relationship of the environment to maximum crop yields will be discussed. Mr. Fike

CS 514 (HS 514) PRINCIPLES AND METHODS IN WEED SCIENCE 3(2-2) S
Prerequisite: CS 414 or equivalent

Studies on the losses caused by the ecology of weeds, biological control, basic concepts of weed management, herbicide-crop relationships and herbicide development. Introduction to greenhouse and bioassay techniques and field research techniques. Messrs. Monaco, Schrader

CS 541 (GN 541, HS 541) PLANT BREEDING METHODS 3(3-0) F
Prerequisites: GN 506, ST 511

An advanced study of methods of plant breeding as related to principles and concepts of inheritance. Messrs. Henderson, Wernsman

CS 542 (GN 542, HS 542) PLANT BREEDING FIELD PROCEDURES 2(0 4) Sum.
Prerequisite: CS 541 (GN 541, HS 541)

Laboratory and field study of the application of the various plant breeding techniques and methods used in the improvement of economic plants. Mr. Harvey

CS 545 (GN 545) ORIGIN AND EVOLUTION OF CULTIVATED PLANTS 2(2-0) S
Prerequisite: CS 541 (GN 541, HS 541) or GN 540 (ZO 540)

Discussion topics include: mankind as a potential cultivator; man's anatomy, physiology and alimentary needs; origins of cultivation; spread of agriculture in terms of various theories; interactions of crops and environments with reference to crop evolution; special attributes of cultigens; modern aspects of evolution (breeding). (Offered in 1972 and alternate years.) Mr. Lee

CS 591 SPECIAL PROBLEMS Credits Arranged
Prerequisite: Consent of instructor

Special problems in various phases of crop science. Problems may be selected or will be assigned. Emphasis will be placed on review of recent and current research. Graduate Staff

FOR GRADUATES ONLY*

CS 613 (GN 613, HS 613) PLANT BREEDING THEORY 3(3 0) S
Prerequisites: CS 541 (GN 541, HS 541), GN 506, ST 512

A study of theoretical bases for plant breeding procedures with special emphasis on the relationship between type and source of genetic variability, mode of reproduction and effectiveness of different selection procedures. The latest experimental approaches to plant breeding will be discussed as well as standard procedures. (Offered in 1972 and alternate years.) Mr. Miller

CS 614 (HS 614, SSC 614) HERBICIDE BEHAVIOR IN PLANTS AND SOILS 3(3-0) F
Prerequisites: BO 551 and CH 223 or consent of instructor

The chemical and physiological processes involved in the behavior of herbicides in plants and soils will be examined. Topics to be discussed include absorption, translocation, metabolism and mechanisms of action of herbicides on plants; reactions, movement and degradation of herbicides in the soil; and interactions among herbicides and other pesticides. Messrs. Monaco, Weber

CS 690 SEMINAR 1(1-0) FS
Prerequisite: Graduate standing

A maximum of two credits is allowed toward the master's degree; however, additional credits toward the doctorate are allowed. Scientific articles, progress reports in research and special problems of interest to agronomists are reviewed and discussed. Graduate Staff

CS 699 RESEARCH Credits Arranged
Prerequisite: Graduate standing

A maximum of six credits is allowed towards the master's degree, but no restrictions toward the doctorate. Graduate Staff

*Students are expected to consult the instructor before registration.

Design

(For a listing of graduate faculty and departmental information see architecture, page 66.)

FOR ADVANCED UNDERGRADUATES

DN 411, 412 ADVANCED VISUAL LABORATORY III, IV 2-4 FS
Prerequisites: DN 311, DN 312

Advanced problems in the fields of painting, sculpture, graphics and photography.

DN 421, 422 HISTORY OF DESIGN III, IV 3(3-0) FS
Prerequisite: DN 122

Specialized historical studies in design fields.

FOR GRADUATES AND ADVANCED UNDERGRADUATES

DN 505 INTRODUCTION TO DESIGN AS TASK 3(0 6) FS Sum.
Prerequisite: Graduate standing in design or consent of school dean

A studio course which approaches design primarily as task. A program of exercises will be undertaken to acquaint the student with the defining of tasks and their interpretation within a designer's power of action. Task as purpose or intention takes precedence over technique, which is considered as emergent from a defined task.

DN 506 INTRODUCTION TO DESIGN AS TECHNIQUE 3(0-6) FS Sum.
Prerequisite: Graduate standing in design or consent of school dean

A studio course which approaches design primarily as technique. A program of exercises will be undertaken to acquaint the student with the techniques available to him and their relationship to existing and potential tasks. Technique as capability takes precedence over task, which is considered as emergent from a designated technique.

DN 507 INTRODUCTION TO DESIGN AS PRACTICE 3(3-0) FS Sum.
Prerequisite: Graduate standing in design or permission of school dean

A seminar course intended to provide a comprehensive overview of current design concepts and activities. Presentations and discussions by School of Design faculty and design practitioners will explore the design fields in terms of issues, attitudes, methods and operations.

DN 511, 512 ADVANCED VISUAL LABORATORY V, VI 2(0 6) FS
Prerequisite: Graduate standing

Advanced experimental studies in visual phenomena related to design.

DN 541 SEMINAR ON IDEAS IN DESIGN 2(2-0) FS
Prerequisite: Graduate standing

An examination of aesthetics and the relationships of philosophic thought to design.

FOR GRADUATES ONLY

DN 611, 612 ADVANCED VISUAL LABORATORY VII, VIII 2(0 6) FS
Prerequisite: Graduate standing

Advanced experimental studies in visual phenomena related to design.

Ecology

GRADUATE FACULTY

Professors: Frederick S. Barkalow, Stanley W. Buol, Douglas S. Chamblee, Arthur W. Cooper, David E. Davis, John W. Duffield, John E. Hobbie, Henry L. Lucas, Bernard S. Martof, Thomas O. Perry, Thomas L. Quay, Robert L. Rabb, Robert Van der Vaart; *Associate Professor:* Larry F. Grand; *Assistant Professors:* Ernest D. Seneca, Udo Blum

The key to survival is not resistance to change, but meeting the challenges of change. Ecology is the science concerned with the interactions of organisms with each other and with their environment. It is an integrative science through which one gains an understanding of biological and physical interrelationships and predicts the consequences of altering one or several components of an ecosystem. Hence, the application and/or the recognition of the principles of ecology in the pursuit of all scientific disciplines is essential to meeting the challenges of change successfully.

Students in a number of basic and applied curricula may elect to minor in ecology at either the master's or doctor's level. The minor provides an opportunity for a coherent picture of the field of ecology, but it is not so confining as to usurp the normal prerogatives of graduate advisory committees in structuring graduate programs.

The ecology minor is an interdepartmental program drawing faculty from the Departments of Botany, Crop Science, Statistics, Entomology, Forestry, Plant Pathology, Soil Science and Zoology. The program is administered by an Ecology Advisory Committee whose chairmanship is on a rotational basis. Additional information may be obtained about the program by writing to one of the faculty members listed above or to Biological Sciences, P. O. Box 5306, North Carolina State University, Raleigh, North Carolina 27607.

The following courses are recognized as ecological or ecologically oriented and have been grouped into certain related areas (for course descriptions see respective departmental listings):

Population Ecology: ZO 517 Population Ecology; ENT 531 Insect Ecology; GN 550 (ZO 550 Experimental Evolution

—*Limnology and Marine Science:* ZO 519 Limnology; ZO 529 (MAS 529) Biological Oceanography; ZO 619 Advanced Limnology

—*Behavior:* ZO 510 Adaptive Behavior of Animals; ZO 610 Current Aspects of Animal Behavior

—*Microbial Ecology:* MB 514 Microbial Metabolism; MB 521 Microbial Ecology; SSC 632 (MB 632) Ecology and Functions of Soil Microorganisms; PP 611 Advanced Plant Nematology; PP 625 (BO 625 Advanced Mycology

—*Terrestrial Ecology:* BO 544 Plant Geography

—*Physiological Ecology:* FOR 452 Silvics; BO 561 Physiological Ecology of Plants

—*Mathematical Biology and Ecology:* BMA 571, 572 (MA 571, 572) Biomathematics I, II

—*Applied Ecology:* ZO 553 Principles of Wildlife Science; ZO 621 Fishery Science; ENT 550 Fundamentals of Insect Control; ENT 562 Agricultural Entomology; ENT 582 (ZO 582) Medical and Veterinary Entomology; FOR 472 Renewable Resource Management; FOR 501 Forest Influence and Watershed Management; FOR 613 Special Topics in Silviculture; HS 514 CS 514) Principles and Methods of Weed Science

The requirements for a minor in ecology are:

Ph.D. Degree: Four ecological courses, including BO ZO 560 (or its equivalent) and either BO-ZO 660 or 661. The other two courses may include BO-ZO 660 or 661 (if both are taken) and courses from those listed above. If two courses from this list are taken, they must be from different designated areas. Courses from this list may not be in the same department as the major.

Master of Science Degree: Three ecological courses, including BO-ZO 560 (or its equivalent) and either BO-ZO 660 or 661. The third course should not be in the same department as the major.

Incoming students may apply equivalent courses toward these requirements at the discretion of their graduate committee. Students minoring in ecology, particularly at the Ph.D. level, are encouraged to take courses in mathematics and statistics, at least ST 511 and ST 512.

Economics

GRADUATE FACULTY

Professor WILLIAM D. TOUSSAINT, *Head*

Professors: ARTHUR J. COUTU, DALE M. HOOVER, LOREN A. IHNEN, H. BROOKS JAMES, PAUL R. JOHNSON, RICHARD A. KING, JAMES G. MADDOX, BERNARD M. OLSEN, JAMES A. SEAGRAVES, RICHARD L. SIMMONS, T. DUDLEY WALLACE, JAMES C. WILLIAMSON, JR.; *Extension Professors:* GEORGE L. CAPEL, T. EVERETT NICHOLS, JR., CHARLES R. PUGH; *Research Professor USDA:* J. GWYN SUTHERLAND; *Professor Emeritus:* ERNST W. SWANSON; *Associate Professors:* DAVID S. BALL, JOE S. CHAPPELL, MAGDI M. EL-KAMMASH, EDWARD W. ERICKSON, ROBERT M. FEARN, CLEON W. HARRELL, JR., E. WALTON JONES, FRED A. MANCUM, JR., GENE A. MATHIA, ERNEST C. PASOUR, JR., R. JAMES PEELER, JR., *Coordinator of Graduate Programs,* RONALD A. SCHRIMPER, RICHARD E. SYLLA, CARL B. TURNER; *Extension Associate Professors:* R. CHARLES BROOKS, ROBERT D. DAHLE, LEIGH H. HAMMOND, ROBERT C. WELLS; *Assistant Professors:* J. BRUCE BULLOCK, GERALD A. CARLSON, W. DOUGLAS COOPER, BRUCE L. GARDNER, D. LESTER HOLLEY, CHARLES P. JONES, JULIUS C. POINDEXTER, JR., C. RICHARD SHUMWAY; *Extension Assistant Professor:* JOHN E. IKERED; *Visiting Assistant Professor:* A. RONALD GALLANT

The Department of Economics offers programs of study leading to the Master of Economics, the Master of Arts in economics, the Master of Science in agricul tural economics and the Doctor of Philosophy degrees. The curriculum includes courses in economic theory, history of economic thought and fields of specializa tion, including econometrics, marketing, agricultural economics, international trade, economic development, labor economics and human resources and business management analysis. Special attention is given in the curriculum to the develop- ment of quantitative analysis skills in economics and to an understanding of economic factors and public policies as they affect regional, national and interna- tional development.

Collateral fields of study include statistics, history, politics, sociology, psychol ogy, education and other related fields.

The increasing emphasis being placed on economic growth and development in the South, the nation and throughout the world has resulted in an increased demand for well trained workers in economics. Graduates of the department with master's degrees have opportunities to work in industry, for federal and state agencies and to teach, particularly in the rapidly expanding community college or junior college systems.

Doctor of Philosophy graduates have opportunities for employment as teachers and research workers in universities throughout the nation. Many also find ex cellent opportunities in various agencies of federal and state government where they are involved in research and educational work. International development agencies employ some graduates, and others find employment in research with commercial firms.

The department is located on the third floor of the D. H. Hill Library and in the basement and on the second floor of Patterson Hall. Graduate students on assistantships or fellowships are provided with office space and equipment, and other graduate students are provided office space when it is available. The de partment has a modern and well-equipped departmental library, including all the major professional journals. Research reports from federal and state govern- mental agencies and from universities throughout the United States also are kept on file.

Computational facilities are excellent for students whose research problems involve extensive analysis of data, as well as for those students who want to learn to do their own programming. The department has a well trained clerical staff and maintains an IBM 1050 Terminal connected to an IBM 360/System Model 75 operated by the Triangle University Computation Center. Access is also available to an IBM 1130 and a 360/System Model 40 located on campus.

FOR ADVANCED UNDERGRADUATES

EC 401 ECONOMIC ANALYSIS FOR NONMAJORS 3(3-0) FS
Prerequisite: EC 205

An intensive treatment of intermediate economic theory of firm, household and market behavior primarily for graduate students desiring a minor in economics at the master's level. Students with an adequate background in economics and mathe- matics will elect EC 501 rather than 401. Topics include demand, production and cost theory, market equilibrium under competitive and non competitive conditions, an introduction to input-output and general equilibrium theory, the spatial arrange- ment of economic activity and problems of economic efficiency.

EC 402 FINANCIAL INSTITUTIONS 3(3-0) FS
Prerequisite: EC 302

An examination of the flow of funds among the principal financial institutions in the American economy; the behavior of the money and capital markets; and the allocation of savings flows into investment expenditures.

EC 407 BUSINESS LAW I 3(3-0) FS
Prerequisite: EC 205, EC 206 or EC 212

A course dealing with elementary legal concepts, contracts, agency, negotiable instruments, sales of personal property and insurance. Uniform commercial code considered under all titles applicable.

EC 408 BUSINESS LAW II 3(3 0) FS
Prerequisite: EC 407

Deals with real property, bailments, partnerships, corporations, chattel mortgages, mortgages on real estate, landlord and tenant, insurance, wills, suretyship, conditional sales and bankruptcy. Uniform commercial code considered under all titles applicable.

EC 410 PUBLIC FINANCE AND FISCAL POLICY 3(3 0) F
Prerequisites: EC 205, EC 206 and EC 301 recommended

An analysis of the economic effects of government taxation and expenditure deci sions. Major attention will be given to current tax policy issues both at the federal level and at the state-local level. A description of different types of budgets and the effect of budgetary policy upon the level of economic activity will also be included.

EC 411 MARKETING METHODS 3(3-0) FS
Prerequisite: EC 205, EC 206 or EC 212

Marketing institutions and their functions and agencies; retailing, market analysis; problems in marketing.

EC 413 COMPETITION, MONOPOLY AND PUBLIC POLICY 3(3-0) FS
Prerequisite: EC 301 recommended but not required

An analysis of the effect of modern industrial structure on competitive behavior and performance, in the light of contemporary price theory and the theory of workable competition. A critical evaluation of the legislative content, judicial interpretation and economic effects of the antitrust laws.

EC 415 FARM APPRAISAL AND FINANCE 3(2 3) F
Prerequisite: EC 303

Examination of the source of the productivity and value of farm inputs; a critical analysis of and practice in the use of farm appraisal procedures currently used for land and buildings; review of the sources of and repayment practices used in short and intermediate credit in agriculture; consideration of the forces operating in the whole economy with an examination of the implications of these changes for both the lender and borrower in agriculture.

EC 420 CORPORATION FINANCE 3(3-0) FS
Prerequisites: EC 205, EC 260

Financial instruments and capital structure; procuring funds, managing working capital; managing corporate capitalization; financial institutions and their work.

EC 422 INVESTMENTS AND PORTFOLIO MANAGEMENT 3(3-0) FS
Prerequisites: EC 205, ST 311

An analysis of the problems in the investment process, which is dichotomized into

security analysis and portfolio management with emphasis on the latter. The approach is to explain briefly what the traditional thinking has been, and to examine closely the modern revolution in investments which emphasizes a quantitative framework to achieve the goal of performance. After describing what an individual investor faces in making decisions, the question of professional management as an alternative is viewed critically.

EC 425 INDUSTRIAL MANAGEMENT 3(3-0) FS
Prerequisite: Junior standing

Principles and techniques of modern scientific management; relation of finance, marketing, industrial relations, accounting and statistics to production planning and control; analysis of economic, political and social influences on production.

EC 426 PERSONNEL MANAGEMENT 3(3-0) FS
Prerequisite: Junior standing

The scientific management of manpower, from the viewpoint of the supervisor and the personnel specialists. A study of personnel policy and a review of the scientific techniques regarding the specific problems of employment, training, promotion, transfer, health and safety, employee service and joint relations.

EC 430 AGRICULTURAL PRICE ANALYSIS 3(3 0) F
Prerequisite: EC 311

Principles of price formation; the role of price in the determination of economic activity; the interaction of cash and future prices for agricultural commodities; methods of price analysis, construction of index numbers, analysis of time series data including the estimation of trend and seasonal variations in prices.

EC 431 LABOR ECONOMICS 3(3 0) FS
Prerequisite: EC 301 recommended but not required

An economic approach to the labor market and to labor market problems includ ing unemployment and the determination of wages, hours and working conditions under various labor market structures. An examination of the economic effects of trade unions and an introduction to the theory of human capital.

EC 432 INDUSTRIAL RELATIONS 3(3-0) FS
Prerequisite: EC 205 or EC 212

Collective bargaining. Analysis of basic labor law and its interpretation by the courts and governmental agencies. An examination of specific terms of labor contracts and their implications for labor and management. An examination of labor objectives and tactics and management objectives and tactics. Problems of operating under the labor contract.

EC 440 ECONOMIC DEVELOPMENT 3(3-0) S
Prerequisite: EC 302

An examination of the institutional background required for national economic development. The conditions apparent for past growth of nations are compared with conditions obtained in presently retarded nations. Conclusions are drawn from this comparison to provide an introduction to the theoretical models of growth.

EC 441 AGRICULTURAL DEVELOPMENT IN FOREIGN COUNTRIES 3(3-0) S
Prerequisite: EC 205 or EC 206 or EC 212

Identification of agricultural problems in underdeveloped countries; a review of economic criteria for analyzing the problems of developing agriculture and the techniques of analysis for solving such problems. Case studies of development programs in various countries will be discussed.

EC 442 Evolution of Economic Ideas 3(3-0) S
Prerequisite: EC 301

An analysis of the development of economic thought and method during the past two centuries. Economics as a cumulative body of knowledge in a context of emerging technology, changing institutions, pressing new problems and the growth of science.

EC 448 International Economics 3(3 0) F
Prerequisites: EC 205 and EC 206 or EC 212

A study of international economics, including trade, investment, monetary relations and certain aspects of economic development. Emphasis upon analytical and policy approaches, although some institutional material is included.

EC 451 Introduction to Econometrics 3(3-0) FS
Prerequisites: EC 301, EC 302 and EC 317 or ST 311

An introduction to the measurement, specification, estimation and interpretation of functional relationships through single equation least squares techniques. Simple and multiple regression, curvilinear regression and various transformations will be used to measure: demand, cost, production, consumption and investment relationships.

EC 460 Specialized Financial Reporting Theory and Practice 3(3-0) F
Prerequisite: EC 361

A study of the specialized valuation and reporting problems relating to consolidated financial statements, business combinations and reorganizations, govern mental and nonprofit organizations, home office and branch relationships, foreign affiliates, estates and trusts, and business firms experiencing financial difficulties. Includes a study of related professional publications.

EC 464 Income Taxation 3(3-0) FS
Prerequisite: EC 260

A study of federal and state income tax laws relating to individuals and other taxable or reporting entities, the measurement and reporting of taxable income, and basic research in taxation. Includes an introduction to tax planning.

EC 466 Examination of Financial Statements 3(3-0) S
Prerequisite: EC 361

A study of the objectives, standards, procedures, problems, practices and theory of financial statement examination as performed by independent public accountants, the professional standards and ethical codes, the features of information systems and internal control, and other professional topics. Includes extensive use of professional literature and authoritative pronouncements.

EC 468 Professional Accountancy Resume 3(3-0) S
Prerequisites: EC 362 and EC 460

A review and summation of the theory and practice of financial reporting and professional accountancy, as they relate to preparation for the certified public accountants examination, covering both their general and specialized topics.

EC 470 (HI 470) Evolution of the American Economy 3(3-0) S
Prerequisites: EC 206 and HI 112 or HI 348 or HI 412

The continuing advances of modern industrialization are related to the development of the American nation. Contemporary problems and issues are analyzed with reference to their origins in the historical growth of the economy.

EC 475 COMPARATIVE ECONOMIC SYSTEMS 3(3-0) F
Prerequisite: EC 205 or EC 206

A general study of different economic systems. Concentration will be given to capitalist or market economies and these will be contrasted with collectivist types of systems. Emphasis will be given to the Soviet economy.

EC 482 (TX 482) SALES MANAGEMENT FOR TEXTILES 3(3-0)S

(See textile technology, page 314.)

EC 490, 491 SENIOR SEMINARS IN ECONOMICS 3(3-0) FS
Prerequisites: EC 301, EC 302

The terminal courses in undergraduate study of economics. The student is assisted in summarizing his training, and in improving his capacity to recognize problems and to select logically consistent means of solving problems. This is done on a small-group and individual basis.

EC 494, 495 (PS 494, 495; SOC 494, 495) URBAN SEMINAR 3(0 3) FS

(See politics, page 265.)

FOR GRADUATES AND ADVANCED UNDERGRADUATES

EC 501 PRICE THEORY 3(3-0) FS
Prerequisites: EC 301 and MA 112 or equivalent

An intensive analysis of the determination of prices and of market behavior, including demand, cost and production, pricing under competitive conditions and pricing under monopoly and other imperfectly competitive conditions.
Messrs. Pasour, Sylla

EC 502 INCOME AND EMPLOYMENT THEORY 3(3-0) FS
Prerequisite: EC 302

A study of the methods and concepts of national income analysis with particular reference to the role of fiscal and monetary policy in maintaining full employment without inflation. Graduate Staff

EC 510 (PS 510) PUBLIC FINANCE 3(3-0) F
Prerequisite: EC 205

A survey of the theories and practices of governmental taxing, spending and borrowing, including intergovernment relationships and administrative practices and problems. Mr. Block, Graduate Staff

EC 515 WATER RESOURCES ECONOMICS 3(3 0) S
Prerequisite: Graduate standing

The application of economic principles in the allocation of water resources. Attention is given especially to the basic issues of how to effect maximum economic efficiency in the use of a resource that is no longer a free good, under the considera tion of the goals of the public and private sectors of the enterprise economy. Both economic and political consequences of decision-making are studied. Graduate Staff

EC 521 MARKETS AND TRADE 3(3-0) F
Prerequisite: EC 301

A study of marketing firms as producers of marketing services and their role in the pricing process; the influence of government policies on the behavior of marketing firms; methods for increasing the efficiency of marketing agricultural products.
Mr. King

EC 523 PLANNING FARM AND AREA ADJUSTMENTS 3(2-2) S
Prerequisite: EC 303

The application of economic principles in the solution of production problems on typical farms in the state; methods and techniques of economic analysis of the farm business; application of research findings to production decisions; development of area agricultural programs. Mr. Liner

EC 525 MANAGEMENT POLICY AND DECISION MAKING 3(3-0) FS
Prerequisite: EC 301

A review and consideration of modern management processes used in making top-level policies and decisions. An evaluation of economic, social and institutional pressures, and of the economic and noneconomic motivations, which impinge upon the individual and the organization. The problem of coordinating the objectives and the mechanics of management is examined. Graduate Staff

EC 533 AGRICULTURAL POLICY 3(3-0) S
Prerequisite: EC 301

A review of the agricultural policy and action programs of the federal government as regards both input supply and commodities, analysis of objectives, principal means and observable results as regards resource use and income distribution within agriculture, and between agriculture and the rest of the economy; appraisal of the effects alternative policy proposals would have on domestic and foreign consumption. Mr. Mangum

EC 535 SOCIAL SCIENCE CONCEPTS IN MANAGERIAL PROCESSES 3(3-0) S
Prerequisite: Six hours in economics

Interrelationships between concepts from economics and from other social sciences in managerial processes of clarifying goals, discovering alternatives and choosing courses of action. Cases are used to provide opportunities to compare contributions of theoretical concepts from economics, political science, social psychology, sociology and management science to managerial processes. Theoretical concepts are drawn from readings in the various disciplines. Graduate Staff

EC 550 MATHEMATICAL MODELS IN ECONOMICS 3(3 0) S
Prerequisites: EC 301, EC 302, MA 212 and MA 405 recommended but not required

An introductory study of economic models emphasizing their formal properties. The theory of individual economic units is presented as a special case in the theory of inductive behavior. Mathematical discussions of the theory of the consumer, the theory of the firm and welfare economics will show the relevance of such topics as constrained maxima and minima, set theory, partially and simply ordered systems, probability theory and game theory to economics. Mr. Harrell

EC 551 AGRICULTURAL PRODUCTION ECONOMICS 3(3-0) F
Prerequisite: EC 301

An economic analysis of agricultural production including: production functions, cost functions, programming and decision-making principles; and the applications of these principles to farm and regional resources allocation, and to the distribution of income to and within agriculture. Mr. Perrin

EC 555 LINEAR PROGRAMMING 3(3-0) FS
Prerequisites: EC 301, MA 212, MA 405

Recent developments in the theory of production, allocation and organization. Optimal combination of integrated productive processes within the firm. Applica tions in the economics of industry and of agriculture. Mr. Harrell

EC 561 (ST 561) INTERMEDIATE ECONOMETRICS 3(3-0) S
Prerequisites: EC 501 and ST 501 or MA 112

The formalization of economic hypotheses into testable relationships and the application of appropriate statistical techniques will be emphasized. Major attention will be given to procedures applicable for single equation stochastic models expressing microeconomic and macroeconomic relationships. Statistical considerations that are relevant in working with time series and cross sectional data in economic investigations will be covered. The use of simultaneous equation models and the available estimation techniques will be surveyed. Mr. Johnson

EC 570 ANALYSIS OF AMERICAN ECONOMIC HISTORY 3(3 0) F
Prerequisite: EC 470 (HI 470) or graduate standing

Stresses the application of economic analysis to the formulation and testing of hypotheses concerning economic growth and development in the historical context. Problems selected for analysis will be drawn primarily from American economic history. Mr. Sylla

EC 574 (SOC 574) THE ECONOMICS OF POPULATION 3(3-0) FS
Prerequisite: EC 301

A review of pre-Malthusian thought up to contemporary population theories. The student is introduced to data sources, statistical tools and methodology for economic analysis in demography. There follows an intensive treatment of microeconomic models of fertility. On the macroeconomic side, economic demographic models are examined. Implications of these economic models for public policy are developed. Underpopulation, overpopulation, optimum growth rate and incentive schemes are discussed. Mr. El-Kammash

EC 585 (TX 585) MARKET RESEARCH IN TEXTILES 3(3-0) S

(See textile technology, page 315.)

EC 590 SPECIAL ECONOMICS TOPICS Maximum 6
Prerequisite: Consent of instructor

An examination of current problems in economics organized on a lecture-discussion basis. The content of the course will vary as changing conditions require the use of new approaches to deal with emerging problems. Graduate Staff

EC 598 TOPICAL PROBLEMS IN ECONOMICS 1-6
Prerequisite: Consent of instructor

An investigation of topics of particular interest to advanced students under the direction of faculty members on a tutorial basis. Credits and content will vary with the needs of the students. Graduate Staff

FOR GRADUATES ONLY

EC 600 ADVANCED PRICE THEORY 3(3-0) FS
Prerequisites: EC 501, MA 212

Alternative economic organizations and the role of prices; equilibrium and price determination in a market economy; theory of consumer behavior; derivation of individual demand curves and aggregation to market supply curves; demand for factors of production. Mr. Gardner

EC 601 PRICES, VALUE AND WELFARE 3(3-0) FS
Prerequisite: EC 600

The supply of factors of production; alternative nonmonetary theories of capital

and interest; productivity; income distribution; determinants of firm size; the nature of market organization; welfare economics topics, including externalities, compensation, social welfare function and consumer surplus. Mr. Wallace

EC 602 ADVANCED INCOME AND EMPLOYMENT THEORY 3(3-0) FS
Prerequisite: EC 502

The course consists of an analysis of the forces determining the level of income and employment; a review of some of the theories of economic fluctuations; and a critical examination of a selected macroeconomic system. Mr. Poindexter

EC 603 HISTORY OF ECONOMIC THOUGHT 3(3-0) FS
Prerequisites: EC 501 and EC 502 or equivalent

A systematic analysis of the development and cumulation of economic thought, designed in part to provide a sharper focus and more adequate perspective for the understanding of contemporary economics. Mr. Turner

EC 604 MONETARY ECONOMICS 3(3-0) F
Prerequisite: EC 502 or equivalent

Consideration of the money market and portfolio management, the cost of capital, effects of monetary phenomena on investment and accumulation of wealth with emphasis throughout on problems arising from uncertainty; general equilibrium theory of money, interest, prices and output. Mr. Lapp

EC 606 INDUSTRIAL ORGANIZATION AND CONTROL 3(3 0) F
Prerequisite: EC 501

Microeconomic theory is applied to the empirical analysis of public policies that affect the efficiency of resource allocation in the U. S. economy. Special attention is given to the interrelationships between industrial structure, conduct and performance. Mr. Erickson

EC 610 THEORY OF PUBLIC FINANCE 3(3 0) FS
Prerequisites: EC 501, EC 502

An application of microeconomic and macroeconomic theory to the budgetary policies of the governmental sector with emphasis on the welfare effects of taxation and expenditure policies and the impact on optimum allocation and distribution of resources. Mr. Hyman

EC 625 LONG RANGE PLANNING IN BUSINESS AND INDUSTRY 3(3 0) S
Prerequisite: EC 501

Theory and practice of long range planning in business and industry. Case discus sions and intensive readings dealing with techniques for identifying opportunities and risks in the environment of the firm, determining corporate strengths and weaknesses, specifying long range strategy. Special attention is given to the roles of management and the internal processes of large organizations as the organizations respond to changes in external conditions. Mr. Dahle

EC 630 LABOR ECONOMICS AND MANPOWER PROBLEMS 3(3-0) S
Prerequisites: EC 501, EC 502

A course devoted to analysis of labor force problems and labor market behavior. Labor force measurement and behavior, the measurement and analysis of unemploy ment, the determinants or relative wages, wage structures, and hours of work and national manpower policy. Emphasis on empirical studies. Mr. Fearn

EC 631 HUMAN CAPITAL 3(3-0) F
Prerequisites: EC 501, EC 502

An examination of human resource development from an economic view.

Emphasis is placed on recent research and theoretical developments related to the economics of education, on the job training, discrimination and migration. Mr. Ihnen

EC 632 ECONOMIC WELFARE AND PUBLIC POLICY 3(3-0) S
Prerequisite: EC 601

Description of the conditions defining optimal resource allocation; application of the conditions for maximum welfare in appraisal of economic policies and programs affecting resource allocation and income distribution. Mr. Hoover

EC 640 ANALYSIS OF ECONOMIC DEVELOPMENT 3(3 0) S
Prerequisite: EC 502

Theoretical and empirical studies of the processes of economic development are compared and analyzed. Contemporary developments in the theories of economic growth are related to the problems of underdeveloped countries. Policies and programs needed for effecting economic development are studied and evaluated for consistency. Mr. Olsen

EC 641 AGRICULTURAL PRODUCTION AND SUPPLY 3(3 0) S
Prerequisites: EC 601, ST 513

An advanced study in the logic of, and empirical inquiry into, producer behavior and choice among combinations of factors and kinds and quantities of output; aggregative consequences of individuals' and firms' decisions in terms of product supply and factor demand; factor markets and income distribution; general interdependency among economic variables. Mr. Seagraves

EC 642 CONSUMPTION, DEMAND AND MARKET INTERDEPENDENCY 3(3-0) F
Prerequisites: EC 601, ST 513

An analysis of the behavior of individual households and of consumers in the aggregate with respect to consumption of agricultural products; the impact of these decisions on demand for agricultural resources; the competition among agricultural regions and for markets; and the interdependence between agriculture and other sectors of the economy. Mr. King

EC 645 PLANNING PROGRAMS FOR ECONOMIC DEVELOPMENT 3(3-0) FS
Prerequisites: EC 550, EC 640

Consideration is given to the necessary quantitative measures for basing plans of national economic development. Models for program development and the techniques for their construction are studied. Mr. Olsen

EC 648 THEORY OF INTERNATIONAL TRADE 3(3-0) S
Prerequisites: EC 501, EC 502

A consideration of the specialized body of economic theory dealing with the international movement of goods, services, capital and payments. Also, a theoreti cally oriented consideration of policy. Messrs. Ball, Johnson

EC 649 MONETARY ASPECTS OF INTERNATIONAL TRADE 3(3-0) S
Prerequisite: EC 502

Study of the macroeconomic problems of an open economy including the balance of payments adjustment mechanism, alternative exchange rate systems, external effects of monetary and fiscal policy, optimum currency areas and international monetary reform. Mr. Grennes

EC 650 ECONOMIC DECISION THEORY 3(3-0) FS
Prerequisite: EC 501 or equivalent, EC 550 or EC 555

Study of general theories of choice. Structure of decision problems, the role of information; formulation of objectives. Current research problems. Mr. Carlson

EC 651 (ST 651) ECONOMETRICS 3(3-0) F
Prerequisites: EC 600, ST 421, ST 502

The role and uses of statistical inference in economic research; the problem of spanning the gap from an economic model to its statistical counterpart; measurement problems and their solutions arising from the statistical model and the nature of the data; limitations and interpretation of results of economic measurement from statistical techniques. Mr. Schrimper

EC 652 (ST 652) TOPICS IN ECONOMETRICS 3(3-0) S
Prerequisite: EC 651 (ST 651)

Survey of current literature on estimation and inference in simultaneous stochastic equations systems. Techniques for combining cross section and time series data including covariance, error correlated and error component models. Lag models and inference in dynamic systems. Production functions, productivity measurement and hypotheses about economic growth. Complete and incomplete prior information in regression analysis. Nonlinear estimation in economic models.
Mr. Wallace

EC 665 ECONOMIC BEHAVIOR OF THE ORGANIZATION 3(3-0) FS
Prerequisite: EC 501

This seminar will apply methods and findings derived from the behavioral sciences to the economic behavior of the organization, particularly the business firm. Among the approaches which may be utilized are organization theory, information theory, reference group theory and decision theory. Graduate Staff

EC 699 RESEARCH IN ECONOMICS Credits Arranged
Prerequisite: Graduate standing

Individual research in economics under staff supervision and direction.
Graduate Staff

Education

GRADUATE FACULTY

Professor CARL J. DOLCE, *Dean*
Professor JAMES B. KIRKLAND, *Dean Emeritus*
Associate Professors: LEONIDAS J. BETTS, JR., PAUL J. RUST; *Adjunct Professor:* THELMA L. ROUNDTREE; *Adjunct Associate Professor:* JOSEPH R. CLARY; *Assistant Professors:* DAVID R. KNIEFEL, BARBARA M. PARRAMORE, THOMAS N. WALTERS; *Instructor:* KATHLEEN A. MCCUTCHEN; *Research Associate:* ROBERT L. MORGAN

The School of Education offers graduate programs leading to the master's degree for students majoring in adult education, agricultural education, industrial arts education, vocational industrial education, guidance and personnel services, mathematics education, psychology, and science education. Graduate students in education may pursue programs leading to the degrees of Master of Science or Master of Education.

The Master of Science degree is regarded as a research degree and as preparation for further graduate study. Programs leading to the Master of Science degree are planned to include a major (20 semester hours) in some specialized area of

education and a minor (10 or more semester hours) in some other field such as psychology or agricultural economics. If two minors are chosen, a minimum of six semester hours will be required in each.

The Master of Education degree is designed to meet the needs of students preparing to teach in the secondary schools and community colleges and to assume leadership positions in adult education programs. The program of study for the professional degree allows a wider latitude in the choice of course work outside the major than is allowed by the Master of Science program.

Graduate programs leading to the Ed.D. degree are offered for majors in adult education and occupational education. The doctoral program is designed to meet the needs of such personnel as teachers. directors, supervisors and teacher educa tors affiliated with programs of vocational and industrial arts education at the local and state level; administrative officers of technical institutes and community colleges; directors of guidance and personnel services; directors of adult basic education; and cooperative extension personnel. Graduate programs will be planned in terms of educational objectives, experience and preparation of the enrollees. However, each program will include courses in such areas as educational foundations, behavioral sciences and research in addition to the specialty area.

Graduate programs leading to the Ph.D. degree are also offered for majors in mathematics education, science education and psychology. The major objective of the doctoral programs in mathematics education and in science education is to prepare leaders in these fields in teaching, supervision and administration. The major objectives of the doctoral program in psychology are to prepare professional psychologists for careers in scientific research and professional academicians for an effective role in the university community. Programs will be planned in terms of the educational objectives and preparation of the enrollees. However, all enrollees will pursue the courses comprising the core. Provisions will be made for specialization in any of the narrower disciplines through additional courses and the minor.

The School of Education is located in the newly completed education building where research and laboratory facilities are provided for graduate study.

Prior to consideration of applications for admission, the following must have been received: a completed application form, a copy of current Graduate Record Examination scores, transcripts for all undergraduate and prior graduate courses taken, and at least three completed recommendation forms. In some programs an interview is required. In order to maintain personalized, quality graduate programs, each program can enroll only a limited number of students irrespective of the qualifications of the applicants.

A limited number of teaching and research assistantships are available for qualified graduate students. National Defense Education Act loans are also availa ble for graduate students needing financial aid.

FOR GRADUATES AND ADVANCED UNDERGRADUATES

ED 504 PRINCIPLES AND PRACTICES OF INTRODUCTION TO VOCATIONS 3(3-0) FS
Prerequisite: Twlelve hours of education

This course is designed for teachers of Introduction to Vocations program in the overall school curriculum, special methods of instruction, use of teaching aids and use of student evaluation instruments. An overview will also be presented in the areas of community organization, job markets, group procedures, occupational and educational information and the changing occupational structure in our society.

Graduate Staff

ED 505 PUBLIC AREA SCHOOLS 3(3 0) F Sum.
Prerequisite: Graduate standing

Junior and community colleges, technical institutes, vocational schools and branches of universities; their development, status and prospects; policy and policy making, clientele, purposes, evaluation programs, personnel, organization, administration, financing, facilities, research and development functions. Graduate Staff

ED 506 EDUCATION OF EXCEPTIONAL CHILDREN 3(3-0) F Sum.
Prerequisite: Six hours of education or psychology

This course is directed toward the understanding of exceptional children and their educational programs. Exceptional children are those who deviate from the so-called normal physically, mentally or emotionally, to the extent that they need some adaptation (methods, materials and grouping, etc.) of the regular school program. Mrs. McCutchen

ED 507 ANALYSIS OF READING ABILITIES 3(3-0) F Sum.
Prerequisite: Six hours of education or psychology

A study of tests and techniques used in determining specific abilities; a study of reading retardation and factors underlying reading difficulties. Mr. Rust

ED 508 IMPROVEMENT OF READING ABILITIES 3(3-0) S Sum.
Prerequisite: Six hours of education or psychology

A study of methods used in developing specific reading skills or in overcoming certain reading difficulties; a study of methods used in developing pupil vocabularies and work analysis skills; a study of how to control vocabulary burden of reading material. Mr. Rust

ED 509 METHODS AND MATERIALS TEACHING RETARDED CHILDREN 3(3-0) F Sum.
Prerequisite: ED 506

Emphasis on understanding and correlating developmental levels of mentally retarded children and appropriate educational methods and materials. Use of individual child's diagnostic data; consideration of long and short range educational goals; curriculum planning in terms of realistic usefulness; scheduling; teacher guidance of children toward social and emotional maturity. Mrs. McCutchen

ED 511 IMPLICATIONS OF MATHEMATICAL CONTENT, STRUCTURE, AND PROCESSES FOR THE TEACHING OF MATHEMATICS IN THE ELEMENTARY SCHOOL 3(3-0) Sum.
Prerequisite: Bachelor's degree in elementary education or consent of instructor

A course designed for teachers and supervisors of mathematics in the elementary school. Special emphasis is given to the implications of mathematical content, structure and processes in teaching arithmetic and geometry in the elementary school. Attention is given to the use of logic and fundamental rules of inference, deductive and inductive reasoning, the field properties in the sets of integers and rational numbers, elementary number theory, metric and non-metric geometry.
Mr. Speece

ED 512 ACTIVE LEARNING APPROACHES TO TEACHING MATHEMATICS IN THE ELEMENTARY SCHOOL 3(3-0) Sum.
Prerequisite: Bachelor's degree in elementary education or consent of instructor

A course that will stress active learning approaches to the teaching of mathematics in the elementary school. Special emphasis will be given to the laboratory approach to teaching mathematics and the use of the manipulative materials and activities of the Nuffield Project, the Madison Project, Dienes, Cuisenaire and Cattegno. Attention will be given to research supporting the laboratory approach

using manipulative materials in the elementary school. Suggestions will be given for designing activities for independent and group study and in assessing individual progress. Mr. Speece

ED 517 IMPLICATIONS FOR DATA PROCESSING IN EDUCATION 3(3-0) FS
Prerequisites: CSC 111; ED 529 or consent of instructor

An intensive study of current attempts to apply new technologies to education. Attention will be given to research findings related to computer assisted instruction, gamed instructional simulation, approaches to guidance and prescription learning as well as administrative problems pertaining to student scheduling, pupil transportation and data reporting systems. Graduate Staff

ED 518 PRINCIPLES OF SCHOOL LAW 3(3-0) FS
Prerequisite: Six hours of graduate credit

This course will be an intensive study of the legal rights, duties, privileges and responsibilities entailed in the educational enterprise. It will cover the essentials of school law in such a way that the student will be able to obtain both a general understanding of the processes of law as they affect American education and also important specific legal aspects which affect vocational education. Included are the secondary, post-secondary and adult vocational education laws and their implications. Mr. Nerden

ED 519 EARLY CHILDHOOD EDUCATION 3(1-4) S Sum.
Prerequisite: PSY 475 or PSY 576

This course is concerned with the planning, selection and utilization of human resources, activities, materials and facilities relating to the education of young children. Emphasis on student observation, participation and evaluation of educational experiences appropriate for the developmental level of individual children, including flexible grouping, curricula planning and instructional techniques for an optimum learning environment. A synthesis of the student's knowledge of human development, learning theory and research findings as related to classroom application. Mrs. McCutchen

ED 526 TEACHING IN COLLEGE 3(3-0) FS Sum.

Designed primarily for graduate students in the departments outside the School of Education, this course focuses on the development of competencies to perform the day-to-day tasks of a college teacher as well as consideration of more long-range tasks such as course development and the university responsibilities of a professor. In addition to attending lectures and other types of presentations, students will make video tapes of their teaching, develop tests, design an introductory course in teaching field and engage in other similar types of activities. Graduate Staff

ED 528 COOPERATIVE OCCUPATIONAL EDUCATION 3(3-0) FS
Prerequisite: Permission of instructor

This course is designed to guide and assist in the growth patterns of individuals who are preparing to be directors, administrators or supervisors of vocational education programs at the local, state and/or national levels, with special emphasis upon the organization and operation of cooperative occupational programs. The course will cover the entire field of cooperative occupational education on secondary, post-secondary and adult levels. It will refer to the accepted essentials of cooperative education in order that the application of the philosophy to the details of planning, organization, establishment and operation of cooperative occupational programs will be practical and meaningful. Included will be student visitations to existing quality programs in cooperative occupational education, for the purpose of studying on-site conditions related to this specialized area of study. Mr. Smith

ED 531 (PSY 531) MENTAL DEFICIENCY 3(3-0) S Sum.
Prerequisite: Nine hours of PSY and special education

This will be a course in description, causation, psychological factors and sociological aspects of mental retardation. Educational methods for the mentally retarded will be examined. The course is designed primarily for school psychologists and special-class teachers of retarded children, both educable and trainable.
Mrs. McCutchen

ED 536 STRUCTURE & FUNCTION OF THE EYE AND USE OF LOW VISION 3(5-0) Sum.
Prerequisite: Consent of instructor

This is a special institute in which participants will spend a minimum of 45 hours in class and class related activities. The instructor and additional consultants (medical and educational) will discuss the structure and function of the eye, eye anomalies likely to affect children with low vision, methods of evaluating type and potential use of residual vision, and methods of teaching children to use minimal vision effectively. Graduate Staff

ED 542 CONTEMPORARY APPROACHES IN THE TEACHING OF SOCIAL STUDIES 3(3-0) Sum.
Prerequisites: Advanced undergraduate or graduate standing; must have completed student teaching

An analysis of the principles, strategies and applications of new teaching approaches. Team-teaching, programmed instruction, inductive and reflective oriented teaching, role-playing, simulation and gaming, independent study and block-time organization will be explored. Graduate Staff

ED 550 PRINCIPLES OF EDUCATIONAL ADMINISTRATION 3(3 0) S Sum.
Prerequisites: Graduate standing, consent of instructor

This course is designed as an introductory course in educational administration. Emphasizing basic principles of administration, the course will draw upon administrative theory, business and public administration models as well as theoretical constructs from various disciplines. Graduate Staff

ED 552 INDUSTRIAL ARTS IN THE ELEMENTARY SCHOOL 3(3-0) Sum.
Prerequisites: Twelve hours of education, consent of instructor

This course is organized to help elementary teachers and principals understand how tools, materials and industrial processes may be used to vitalize and supplement the elementary school child's experiences. Practical children's projects along with the building of classroom equipment. Graduate Staff

ED 563 EFFECTIVE TEACHING 3(3-0) FS Sum.
Prerequisite: Twelve hours of education including student teaching

Analysis of the teaching-learning process; assumptions that underlie course approaches; identifying problems of importance; problem solution for effective learning; relationship of learning and doing; responsibility for learning; evaluation of teaching and learning; making specific plans for effective teaching.
Graduate Staff

ED 597 SPECIAL PROBLEMS IN EDUCATION 3(0-0) FS Sum.
Prerequisites: Graduate standing and consent of instructor

This course is designed to provide graduate students in education the opportunity to study problem areas in professional education under the direction of a member of the graduate faculty. Graduate Staff

FOR GRADUATES ONLY

ED 602 CURRICULUM 3(3-0) FS
Prerequisites: PSY 510, PSY 535, ED 503 and/or comparable course in occupational education

A course designed to equip the student with the conceptual tools and intellectual skills needed to develop and critically assess curricula in all educational fields. The elements of the curriculum development process that are studied in the course include: identification and formulation of educational objectives, selection of learning experiences, developing and implementing plans for evaluating learning experiences and assessing educational outcomes, and staff-leader involvement in the curriculum development process. Graduate Staff

ED 608 SUPERVISION OF VOCATIONAL AND INDUSTRIAL ARTS EDUCATION 3(3-0) F
Prerequisites: ED 527, ED 554, ED 609, ED 630 or equivalents

An intensive study of the principles of supervision and the applications of these principles to the vocational and industrial arts education programs being conducted in secondary, post-secondary and adult facilities. Emphasis is placed upon the competencies needed in supervisors in order to effectively discharge their responsibilities in such areas as teacher selection, teacher transfer and promotion, assistance in teacher professional growth, the conduct of workshops and in service programs for professional and nonprofessional staff, self evaluative processes in education, curriculum generation and modification, guidance and counseling provisions and action research. Messrs. Hanson, Nerden, Graduate Staff

ED 610 ADMINISTRATION OF VOCATIONAL AND INDUSTRIAL ARTS EDUCATION 3(3 0) S
Prerequisites: ED 527, ED 554, ED 609, ED 630 or equivalent

An intensive study of the major elements of administrative practice applied to vocational and industrial arts education, as it is being conducted in comprehensive high schools, comprehensive community colleges, technical institutes and area vocational centers. Emphasis is placed upon leadership, personnel management, instructional program management and evaluation, public relations and financial management, in connection with preparatory, part-time supplementary, extension and adult education programs of vocational and industrial arts education.
Messrs. Hanson, Nerden, Graduate Staff

ED 614 MODERN PRINCIPLES AND PRACTICES IN SECONDARY EDUCATION 2(2 0) FS
Prerequisite: Twelve hours of education

Foundations of modern programs of secondary education purposes, curriculum, organization, administration, and the place and importance of the high school in the community in relation to contemporary social force. Graduate Staff

ED 615 INTRODUCTION TO EDUCATIONAL RESEARCH 3(3-0) FS Sum.
Prerequisite: PSY 535 or equivalent

An introductory course for students preparing for an advanced degree. The purposes are: to assist the student in understanding the meaning and purpose of educational research and the research approach to problems; to develop the student's ability to identify educational problems, and to plan and carry out research to solve these problems; to aid in the preparation of the research report. Special attention is given to tools and methods of research. Consideration is also given to the educator as a consumer of research. Graduate Staff

ED 620 CASES IN EDUCATIONAL ADMINISTRATION 3(3-0) S Sum.
Prerequisites: Graduate standing and consent of instructor

This course utilizes the case study and case simulation approach to the study of

school administration. Administrative concepts will be developed and applied to simulated situations and to actual case histories. The administrative process is viewed as a decision-making process. The student will be expected to make decisions after considering alternative courses of action and after projecting probable consequences. Graduate Staff

ED 621 INTERNSHIP IN EDUCATION 3-9 FS Sum.
Prerequisites: Nine credit hours in graduate level courses in education and consent of instructor

Utilizing the participant-observer role, this course requires participation in selected educational situations with emphasis upon development of observational skills, ability to record relevant observations by means of written journals, skills in analyzing experiences identifying critical incidents, and prediction of events and consequences. The student is required to develop possible alternative courses of action in various situations, select one of the alternatives and evaluate the consequences of the course of action selected. Graduate Staff

ED 665 SUPERVISING STUDENT TEACHING 3(3-0) FS Sum.
Prerequisite: Twelve hours of education

A study of the program of student teaching in teacher education. Special consideration will be given the role of the supervising teacher including the following areas: planning for effective student teaching, observation and orientation, school community study, analysis of situation, evaluating student teachers and coordination with North Carolina State University. Graduate Staff

ED 688 RESEARCH APPLICATION IN OCCUPATIONAL EDUCATION 3(3-0) FS Sum.
Prerequisite: ED 615

This course will be concerned with methodology, application, analysis and synthesis of research in occupational education. A review of current occupational education studies, clustered by areas, will be made with attention to statistical techniques, data collecting, data handling, and the audience and impact of particular projects and research organizations. The class activities in research application are designed to bridge the gap between the theories of research methodology and the student's independent research projects. Graduate Staff

ED 689 EVALUATION IN OCCUPATIONAL EDUCATION 3(3-0) FS Sum.
Prerequisites: ED 615, ST 513

This course will be concerned with the conceptual and methodological aspects of occupational education evaluation, with attention to techniques for determining empirically the extent to which educational goals are being achieved, to locate the barriers to the advancement of these goals and to discover the consequences of educational programs. Graduate Staff

ED 697 (PSY 697) ADVANCED SEMINAR IN RESEARCH DESIGN 3(3-0) S
Prerequisites: Nine hours of statistical methods and research or consent of instructor, advanced graduate standing

This course will be designed as a seminar-type course, with topics selected each semester in accordance with the interests and needs of the students. Attention will be given to the research strategies that underlie education and psychological research, to the development of theoretical constructs, to a critical review of research related to problems in which the students are interested, and to a systematic analysis and critique of research problems in which the students are engaged. Mr. Coster

ED 698 SEMINAR IN OCCUPATIONAL EDUCATION 3(3-0) F
Prerequisites: Nine hours in occupational education or consent of instructor, advanced graduate standing

This course will be designed as a seminar type course, with topics selected each semester. Attention will be given to the broad concepts of occupational education as manifested in the Vocational Education Amendments of 1968, and to the problems and issues underlying the development of and implementation of programs of occupational education at elementary junior high, senior high and post-secondary levels, with emphasis on articulation between career choice and preparation for gainful employment. Mr. Coster

ED 699 RESEARCH Credits Arranged
Prerequisites: Fifteen hours, consent of adviser

Individual research on a specific problem of concern to the student.
Graduate Staff

NOTE: A description of the specialized courses offered by the several departments in the School of Education may be found on the following pages: Adult and Community College Education, pages 59-61, Agricultural Education, pages 61-63; Guidance and Personnel Services, pages 173-175; Industrial and Technical Education, pages 184-187; Mathematics and Science Education, pages 218-220; Psychology, pages 275-283.

Electrical Engineering

GRADUATE FACULTY

Professor GEORGE B. HOADLEY, *Head*
Professor WILLIAM D. STEVENSON, JR., *Associate Head and Graduate Administrator*
Professors: WILLIAM J. BARCLAY, ARTHUR R. ECKELS, WALTER A. FLOOD, DONALD R. RHODES, JOHN STAUDHAMMER, FREDERICK J. TISCHER; *Adjunct Professor:* GERHARD K. MEGLA; *Associate Professors:* NORMAN R. BELL, ALFRED J. GOETZE, JOHN R. HAUSER, MICHAEL A. LITTLEJOHN, EDWARD G. MANNING, NEELY F. J. MATTHEWS, LARRY K. MONTEITH, JOHN B. O'NEAL, JR., WILBUR C. PETERSON; *Adjunct Associate Professors:* JOHN D. SPRAGINS, JIMMIE J. WORTMAN; *Assistant Professors:* JAMES W. GAULT, TILDON H. GLISSON, JR., JAMES F. KAUFFMAN, RAYMOND W. STROH; *Adjunct Assistant Professor:* CHARLES C. TAPPERT; *Visiting Assistant Professor:* MOHAMED G. ZAALOUK

The Department of Electrical Engineering offers the degrees of Master of Electrical Engineering, Master of Science and Doctor of Philosophy.

Four core courses (EE 512, EE 520, EE 530, EE 540 are required for the Master of Electrical Engineering degree, and the student must pass a written comprehensive examination in addition to the oral examination. No thesis is required for this degree.

The Master of Science degree has no specified course requirements and no written examination. The thesis may account for as many as six semester hours.

In the more advanced study for the doctorate, a comprehensive understanding of all fields of electrical engineering is required, and specialization appears in the research problem undertaken.

Advanced courses of a general and fundamental nature are required for those who plan to carry their advanced studies to the level of the doctorate. Minor sequences of study in advanced mathematics, physics or other appropriate discipline are planned to fit the needs of individual students.

The laboratories in the department are exceedingly well equipped for research in communications, computers, electromagnetics, solid-state materials and devices, and automatic control. Active research is in progress in these and other areas.

FOR ADVANCED UNDERGRADUATES

EE 401 ADVANCED ELECTRIC CIRCUITS 3(3-0) FS
Prerequisites: EE 202, MA 301

Transient analysis of electric circuits by the Laplace transform method, and the relationship of this method of analysis to steady-state performance, with emphasis on feedback systems.

EE 403 ELECTRIC NETWORK DESIGN 3(3 0) S
Prerequisite: EE 401

The study of design methods for such electric networks as resonant systems, filters, feedback stabilizers, audio amplifier compensation and dividing networks.

EE 430 ESSENTIALS OF ELECTRICAL ENGINEERING 4(3-3) F
Prerequisite: EE 202 or EE 332
Not available to undergraduates in EE.

Essential theory of electric circuits, including solid-state devices, transformers and rotating machines as needed to supply the electrical background for instrumentation and control theory. Intended primarily for graduate students who do not have an electrical engineering undergraduate degree.

EE 431 ELECTRONICS ENGINEERING 3(2-3) F
Prerequisite: EE 314

Comprehensive study of circuits using discrete and integrated electron devices: amplifiers, oscillators, wave-shaping circuits, nonsinusoidal generators, feedback. Emphasis is on design of solid state circuits through development of analytical methods using graphical, slide-rule and computer techniques.

EE 432 COMMUNICATION ENGINEERING 3(2-3) S
Prerequisite: EE 431

Application of electronic circuits to communication systems employing amplitude, angle and pulse modulation. Elements of complete systems: modulators, demodula tors, transmitters and receivers. Introduction to information theory and noise.

EE 433 ELECTRIC POWER ENGINEERING 3(2-3) S
Prerequisite: EE 305 or EE 332

Electrical power supply for industrial and commercial applications; control of electrical motor drives; system safety and protection; practice in testing electrical machines.

EE 434 POWER SYSTEM ANALYSIS 3(3-0) F
Prerequisite: EE 305

Analysis of problems encountered in the long-distance transmission of electric power. Line parameters by the method of geometric mean distances. Circle diagrams, symmetrical components and fault calculations. Elementary concepts of power system stability. Applications of digital computers to power-system problems.

EE 435 ELEMENTS OF CONTROL 3(2-3) F
Prerequisites: EE 314, EE 305; or EE 430

Introductory theory of open- and closed-loop control. Functions and performance requirements of typical control systems and system components. Dynamic analysis of error detectors, amplifiers, motor, demodulators, analogue components and switching devices. Component transfer characteristics and block diagram representation.

EE 438 ELECTRONIC INSTRUMENTATION 3(3-0) S
Prerequisites: MA 301; EE 430 or EE 314 or EE 334

A survey of electrical-electronic measurement techniques and operating principles of electronic instruments. Includes a study of signal sources and their equivalent circuits, basic electronics including junction and field effect transistors, operational amplifiers, switching logic and data display. Applications including low-level phenomena and noise problems will be included, with many lecture demonstrations.

EE 440 FUNDAMENTALS OF DIGITAL SYSTEMS 3(3-0) FS
Prerequisite: EE 314 or EE 430

The basic theory of digital computation and control. Introduction to number systems, data handling, relay algebra, switching logic, memory circuits, the application of electronic devices to switching circuits and the design of computer control circuits.

EE 441 INTRODUCTION TO ELECTRON DEVICES 3(3-0) F
Prerequisites: MA 301; PY 207 or PY 208

A study of the basic physical principles necessary for understanding modern electronic devices. Quantum and statistical mechanic concepts are introduced at an elementary level, and these ideas form the basis for a discussion of a wide variety of devices which are used in modern engineering and instrumentation.

EE 442 INTRODUCTION TO SOLID-STATE DEVICES 3(3-0) S
Prerequisites: EE 441 or PY 407; MA 301

An introduction to the microscopic phenomena responsible for the operation of solid-state electronic devices. A qualitative description of the band model of solids is followed by a description of the transport properties of charge carriers. P n junction diodes and transistors, solar cells, controlled rectifiers, tunnel diodes and unijunction transistors are treated along with more recently developed devices.

EE 445 INTRODUCTION TO ANTENNAS 3(2-3) F
Prerequisites: EE 304, EE 314

An introduction to antenna engineering. Consideration will be given to radiation from single element radiators, radiation patterns, directive properties aperture concepts, gain and impedances. Multielement antennas and arrays with various amplitude distributions and phasings, and thin linear antennas will be treated in some detail. Antennas of current usage.

EE 448 INTRODUCTION TO MICROWAVES 3(2-3) S
Prerequisites: EE 304, EE 314

A study of the elementary theory and special techniques required at microwave frequencies. Both passive and active circuits will be considered. Transmission elements, special-purpose components, generators, to include klystrons, magnetrons, traveling wave tubes, and solid-state devices will be discussed. The description of microwave networks by the scattering matrix will be presented.

FOR GRADUATES AND ADVANCED UNDERGRADUATES

EE 503 COMPUTER-AIDED CIRCUIT ANALYSIS 3(3-0) F
Prerequisites: EE 314, EE 401, B average in electrical engineering and mathematics

Analysis of electrical circuits with emphasis on computer methods. Steady state and transient analysis of linear and nonlinear networks; tolerance analysis; programming considerations. Mr. Staudhammer

EE 504 INTRODUCTION TO NETWORK SYNTHESIS 3(3-0) F
Prerequisites: EE 401, B average in electrical engineering and mathematics

A study of the properties of network functions and the development of the methods of network synthesis of one-port and two-port passive structures. Mr. Hoadley

EE 506 DYNAMICAL SYSTEMS ANALYSIS 3(3-0) F
Prerequisites: EE 202 or EE 331; EM 301; MA 301; B average in electrical engineering, engineering mechanics and mathematics

A study of dynamic systems in various branches of engineering and science with emphasis on the similarities that exist among such integrated groups of devices. Analogous elements and quantities in these fields as determined from equations basic to each. Analytical formulation of system problems in acoustical, electrical, mechanical and related fields and their solution by analog methods. Use of computers for the solution of system problems. Mr. Eckels

EE 511 ELECTRONIC CIRCUITS 3(3-0) F
Prerequisites: EE 314 or EE 430, B average in electrical engineering and mathematics

Electronic devices in amplifiers, feedback systems, oscillators, modulators, switching and wave-shaping circuits. Generation of nonlinear waveforms; electronic instruments; circuits basic to electronic computers. Use of complex frequency concepts to obtain generalized response. Communication, power and industrial applications. Synthesis of circuits to satisfy system requirements. Mr. Barclay

EE 512 COMMUNICATION THEORY 3(3-0) F
Prerequisites: EE 314, B average in electrical engineering and mathematics

Material basic to information-bearing signals in linear systems. Signals in the frequency and time domains, probability and associated functions, random signal theory, modulation and frequency translation, noise, sampling theory and correlation functions. Principles of information theory including information measure, signal space and channel capacity. Fundamentals of encoding. Accent on methods and problems unique to the field of digital communication. (Offered fall every year, summer 1972 and spring 1974.) Messrs. Barclay, Goetze, O'Neal

EE 516 FEEDBACK CONTROL SYSTEMS 3(3-0) S
Prerequisites: EE 435 or EE 401, B average in electrical engineering and mathematics

Study of feedback systems for automatic control of physical quantities such as voltage, speed and mechanical position. Theory of regulating systems and servomechanisms. Steady state and transient responses. Evaluation of stability. Transfer function loci and root locus plots. Analysis using differential equation and operational methods. System compensation and introduction to design.
Mr. Peterson

EE 517 CONTROL LABORATORY 1(0-3) S
Corequisite: EE 516

Laboratory study of feedback systems for automatic control of physical quantities such as voltage, speed and mechanical position. Characteristics of regulating systems and servomechanisms. The laboratory work is intended to contribute to an understanding of the theory developed in EE 516. Mr. Peterson

EE 520 FUNDAMENTALS OF LOGIC SYSTEMS 3(3-0) F
Prerequisites: EE 314 or EE 430, B average in electrical engineering and mathematics

A study of elementary machine language theory, computer organization and

logical design, logical algebras and function minimization (map method emphasized). Introductory combinational and sequential logic including circuits, basic building blocks, and theory construction using electronic and core elements. (Offered fall every year, spring 1972 and 1976 and summer 1974.)
Messrs. Bell, Staudhammer

EE 521 DIGITAL COMPUTER TECHNOLOGY AND DESIGN 3(3-0) S
Prerequisite: EE 520

A study of the internal organization and structure of digital systems including gates, toggle circuits, pulse circuitry and advanced machine language theory. Analysis and synthesis of the major components of computers, including the logic section, counters, storage devices, registers, input-output and control.
Messrs. Bell, Staudhammer

EE 530 PHYSICAL ELECTRONICS 3(3-0) F
Prerequisites: EE 304, B average in electrical engineering and mathematics

A study of behavior of charged particles under the influence of fields and other charged particles. Ballistics, quantum mechanics, particle statistics, electron emission and properties of dielectric and magnetic materials. (Offered fall every year, summer 1973 and spring 1975.) Mr. Matthews

EE 533 INTEGRATED CIRCUITS 3(3-0) S
Prerequisites: EE 314, B average in electrical engineering and mathematics

A study of the implementation of solid-state circuits in integrated form. Includes characteristics of epitaxial, diffused, thin and thick film approaches. Digital and linear applications are examined. Mr. Manning

EE 535 (MAE 535) GAS LASERS 3(3-0) FS

(See mechanical and aerospace engineering, page 225.)

EE 540 ELECTROMAGNETIC FIELDS AND WAVES 3(3 0) F
Prerequisites: EE 304, B average in electrical engineering and mathematics

Laws and concepts of static electromagnetism. Fundamental equations and their applications. Fundamentals, forms and applications of Maxwell's equations. Vector and scalar potentials, relativistic aspects of fields, energy and power. Waves in unbounded and bounded regions, radiation, waveguides and resonators. (Offered fall every year, spring 1973 and summer 1975.) Mr. Tischer

EE 545 INTRODUCTION TO RADIO WAVE PROPAGATION 3(3-0) S
Prerequisites: EE 304, B average in electrical engineering and mathematics

Characteristics of plane electromagnetic waves in homogeneous and nonhomogeneous media with application to tropospheric and ionospheric propagation. Relationships between electron density, collision frequency and complex refractive index, theory of the formation and dynamics of ionospheric layers and theorems for the prediction of ionospheric propagation. Mr. Flood

EE 591, 592 SPECIAL TOPICS IN ELECTRICAL ENGINEERING 3(3-0) FS
Prerequisite: B average in technical subjects

A two-semester sequence to develop new courses and to allow qualified students to explore areas of special interest. Graduate Staff

EE 593 INDIVIDUAL TOPICS IN ELECTRICAL ENGINEERING 1 3 FS
Prerequisite: B average in technical subjects

A course providing an opportunity for individual students to explore topics of special interest under the direction of a member of the faculty.

FOR GRADUATES ONLY

EE 610 NON-LINEAR ANALYSIS 3(3-0) F
Prerequisites: EE 516; or EE 430, MA 405

Methods of analysis of non linear systems. Linear stability criteria applied to certain non linear systems. Liapunov stability for dynamic systems in general. Optimal control systems with quadratic index of performance. (Offered 1973-74 and alternate years.) Mr. Goetze

EE 611 ELECTRIC NETWORK SYNTHESIS 3(3-0) S
Prerequisite: EE 504

A study of modern network theory with emphasis on the synthesis of both passive and active transmission networks based on the work of Cauer, Darlington, Piloty and others. Development of solutions for the approximation and eventual realization of two ports based on specified performance data. Extensive use of digital computers, mostly prepared programs. Basic knowledge of programming advisable. Mr. Hoadley

EE 613, 614 ADVANCED FEEDBACK CONTROL 3(3 0) FS
Prerequisite: EE 516

An advanced study of feedback systems for the control of physical variables. Follower systems and regulators. Mathematical description of systems by use of state variables. Stability theory and performance criteria. Sensitivity analysis. Introduction to non-linear systems and optimization theory. Continuous and sampled data systems. Mr. Peterson

EE 616 MICROWAVE ELECTRONICS 3(3-0) S
Prerequisite: EE 540

Frequency limitations of conventional electron devices. Microwave power generation and control by interaction of electromagnetic fields with charged particles and molecular energy levels, and by nonlinear reactances. Applications in klystrons, magnetrons, traveling wave devices, lasers, masers and reactance amplifiers. Measurement problems and techniques in the microwave region. (Offered 1973-74 and alternate years.) Mr. Barclay

EE 617 PULSE AND DIGITAL CIRCUITS 3(3-0) S
Prerequisite: EE 533

Integrated and discrete circuit techniques for the production, shaping and control of nonsinusoidal wave forms. Fundamental circuits and systems needed in digital information systems, instrumentation and computers. Mr. Barclay

EE 618 ANTENNAS AND RADIATION 3(3 0) F
Prerequisite: EE 540

A research course in radiating electromagnetic systems. Physical principles of analysis and synthesis of antennas as derived from the Maxwell theory of electromagnetism. Investigation of radiative and reactive properties. Conditions for physical realizability. Construction of realizable aperture distributions and space factors. Mr. Rhodes

EE 619 GUIDED WAVES AND RESONATORS 3(3-0) S
Prerequisite: EE 540

A study related to guided waves and resonators with emphasis on microwaves and millimeter waves. The effect of boundaries on wave propagation and the means of guiding waves from a general viewpoint beginning with electromagnetic waves. The analogies with other types of waves such as acoustic and plasma waves.

Nonconventional waveguide concepts. Derivation of general relationships for resonators and for their incorporation in communication systems. (Offered 1972-73 and alternate years.) Mr. Tischer

EE 622 ELECTRONIC PROPERTIES OF SOLID STATE MATERIALS I 3(3-0) S
Prerequisite: EE 530

A study of the electronic properties of solids; details of crystal structure, lattice properties and electronic energy states. Emphasis on properties of special importance in solid-state devices. Mr. Monteith

EE 623 ELECTRONIC PROPERTIES OF SOLID-STATE MATERIALS II 3(3-0) F
Prerequisite: EE 622

Detailed treatment of thermal and electrical transport phenomena, equilibrium and non-equilibrium semiconductor statistics. Also optical properties and hot electron effects in solid state materials. Mr. Monteith

EE 624 ELECTRONIC PROPERTIES OF SOLID-STATE DEVICES 3(3-0) S
Prerequisite: EE 623

Detailed treatment of thermal and electrical transport phenomena, equilibrium and non-equilibrium semiconductor statistics. Also optical properties and hot electron effects in solid-state materials. (Offered 1972 73 and alternate years.)
Mr. Monteith

EE 625 ADVANCED SOLID STATE DEVICE THEORY 3(3-0) F
Prerequisite: EE 624

A study of the latest development in solid state devices. The properties of metal-insulator semiconductor devices, high-field devices and optical devices. Emphasis on the basic fundamental physical principles of operation as opposed to circuit applications. (Offered 1973-74 and alternate years.) Mr. Hauser

EE 640 ADVANCED LOGIC CIRCUITS 3(3-0) S
Prerequisite: EE 520

Topics in advanced logic including symmetric and iterative circuits, multi output and compound-input circuits, Boolean simultaneous equations, Boolean matrix theory, operator theory and threshold logic. Messrs. Bell, Gault

EE 641 SEQUENTIAL MACHINES 3(3 0) F
Prerequisite: EE 520

The study of finite automata, both synchronous and asynchronous. Machine equivalence and minimization, state identification and the state assignment problem. Flip-flop activation from the state diagram and other realization tech niques. Messrs. Gault, Staudhammer

EE 642 AUTOMATA AND ADAPTIVE SYSTEMS 3(3 0) S
Prerequisite: EE 520

The study of neural nets in natural systems, artificial nerve nets, artificial intelligence, goal-directed behavior, the logic of automata and adaptive Boolean logic. Computability, Turing machines and recursive function theory.
Messrs. Bell, Gault

EE 651 STATISTICAL COMMUNICATION THEORY 3(3 0) S
Prerequisites: EE 401; EE 512 or MA 541 (ST 541)

Generalized waveform analysis including Fourier transforms, correlation functions and other statistical descriptions of stationary random processes; manipulation of signal descriptions as affected by linear time-invariant networks;

derivation of the optimum impulse response and transfer function of the general linear operator; optimum filter synthesis by the use of orthonormal functions; problems to illustrate the applications of the theory.

Messrs. Glisson, Stroh

EE 652 INFORMATION THEORY 3(3 0) F
Prerequisite: EE 512

Definition of a measure of information and a study of its properties, information sources and their efficient representation, communication channels and their capacity, encoding and decoding of data for transmission over noisy channels, source encoding systems, error correcting codes, rate distortion bounds.

Mr. O'Neal

EE 653 FUNDAMENTALS OF SPACE COMMUNICATIONS 3(3-0) S
Prerequisite: EE 540

An analytical study of communications related to space operations with emphasis on electromagnetics and antennas. Wave propagation along the transmission path in nonuniform and nonisotropic media. Ionospheric propagation and plasma sheath effects. Antenna characteristics for space operations on ground and on vehicles. Large surface radiators, phased arrays and low noise structures. Vehicle born antennas. Problems of signal transmission. Communication by lasers. (Offered 1973-74.) Mr. Tischer

EE 654 COMMUNICATION SYSTEMS ANALYSIS 3(3-0) S
Prerequisite: EE 512

Tools for the analysis of RF and optical communication systems information symbols, communication path, information content, and entropy and redundancy of an information source. Properties of the communication channel including propagation media and losses, antennas, signal processing and signal quality. The analysis of terrestrial, extra terrestrial and hydrospace systems.

Messrs. Megla, Flood

EE 655 WAVE PHENOMENA IN PLASMA 3(3 0) S
Prerequisite: EE 616 or EE 618 or EE 619 or EE 653

An advanced analysis of wave phenomena and oscillations in plasma. Electron and ion orbits, plasma characteristics and their derivations. Statistical particle dynamics and wave interaction. Macroscopic theory of field interactions, oscillations and waves, Landau damping. Relativistic effects. Wave propagation in and radiation from stationary and moving plasma. (Offered 1971-72 and 1975-76.)

Mr. Tischer

EE 659 PATTERN RECOGNITION 3(3-0) F
Prerequisite: EE 512

A study of pattern recognition techniques, including discriminant functions, parametric and nonparametric training methods, multilayered networks and feature extraction, classification schemes; principal component analysis, discriminant analysis, clustering techniques. Applications to topics of current interest. Messrs. Tappert, Goetze

EE 691, 692 SPECIAL STUDIES IN ELECTRICAL ENGINEERING 3(3-0) FS

An opportunity for small groups of advanced graduate students to study topics in their special fields of interest under the direction of members of the graduate faculty.

EE 695 ELECTRICAL ENGINEERING SEMINAR 1(1 0) FS
Prerequisite: Graduate standing in electrical engineering

A series of papers and conferences participated in by the instructional staff, invited guests and students who are candidates for advanced degrees.

Graduate Staff

EE 699 ELECTRICAL ENGINEERING RESEARCH Credits Arranged
Prerequisites: Graduate standing in electrical engineering, consent of adviser.

Graduate Staff

Engineering Mechanics

GRADUATE FACULTY

Professor PATRICK H. MCDONALD, *Head*
Professor ROBERT A. DOUGLAS, *Associate Head*
Professors: TIEN-SUN CHANG, JOHN A. EDWARDS; *Associate Professors:* WILLIAM L. BINGHAM, MAURICE H. CLAYTON, EDWARD D. GURLEY, CLARENCE J. MADAY, F. YATES SORRELL, *Graduate Administrator; Assistant Professors:* C. M. CHANG, RAYMOND P. GOGOLEWSKI, YASUYUKI HORIE, THOMAS E. SMITH; *Adjunct Assistant Professor:* DONALD I. MCREE

The Department of Engineering Mechanics offers graduate programs leading to the Master of Science, Master of Engineering Mechanics and Doctor of Philosophy degrees. Generally, students who plan to teach or to specialize in research pursue the Master of Science or Doctor of Philosophy degrees, while students who wish to apply advanced concepts to engineering problems find the Master of Engineering Mechanics particularly useful.

Graduate studies in engineering mechanics embrace several broad areas including fluid mechanics, solid mechanics, continuum mechanics, dynamics and structural mechanics. Each of these areas is of considerable importance in current research. Professional interests of the faculty are represented by courses devoted to the elastic and plastic behavior of solids, viscous and compressible fluid flow, the generalized behavior of matter when described as a continuum, and in sequences devoted to the theory of periodic and aperiodic vibrations and to space mechanics.

Graduate research in any of the major areas outlined may follow the lines of either analytical and experimental investigations, and the department seeks to further both in good balance and mutual support. The department particularly encourages the development of new research techniques and methods, and the exploration of frontiers of material behavior.

The laboratories complex of the department is particularly suited to contemporary research. Individual laboratories are devoted to the study of turbulence, to strong shock waves and radiative energy transfer in gases, to the behavior of solids from quasi static to high velocity impact conditions, and to static and dynamic studies in stress concentration. A well-equipped and staffed machine shop maintained by the department is particularly helpful in further graduate research efforts.

The faculty of the department offers a range of graduate courses both for its own students seeking advanced degrees and for inclusion in the graduate programs

of students in allied areas of engineering and in the physical and mathematical sciences. Courses for individual programs of study may be chosen rather broadly from the listings indicated below and from courses appropriate to mechanics studies selected from closely allied engineering specialities. Beginning graduate students ordinarily will choose a program to encompass several of the major areas, thus establishing a broad base for subsequent studies at the advanced graduate level, usually concentrated about one particular area of research. EM 501, 502, Continuum Mechanics I, II, for master's degree students, and EM 601, 602, Unifying Concepts in Mechanics I, II, for Ph.D. candidates, are especially recommended.

Interdisciplinary graduate programs in the areas of mechanics, electrotechnics and materials are encouraged.

Participation in research projects as research assistants and serving as teaching assistants in the department's instructional program are each considered to be highly valuable experience during the program of studies.

FOR GRADUATES AND ADVANCED UNDERGRADUATES

EM 501, 502 CONTINUUM MECHANICS I, II 3(3 0) FS
Prerequisites: EM 301, EM 303, MAE 301, MA 405

The concepts of stress and strain are presented in generalized tensor form. Emphasis is placed on the discussion and relative comparisons of the analytical models for elastic, plastic, fluid, viscoelastic, granular and porous media. The underlying thermodynamic principles are presented, the associated boundary value problems are formulated and selected examples are used to illustrate the theory. Mr. T. S. Chang

EM 503 THEORY OF ELASTICITY I 3(3-0) F
Prerequisite: EM 301
Corequisite: MA 511 or MA 401

The fundamental equations governing the behavior of an elastic solid are developed in various curvilinear coordinate systems. Plane problems, as well as the St. Venant Problem of Bending, Torsion and Extension of bars are covered. Displacement fields, stress fields, Airy and complex stress functions are among the methods used to obtain solutions. Messrs. Douglas, T. E. Smith

EM 504 MECHANICS OF IDEAL FLUIDS 3(3-0) F
Prerequisite: EM 304
Corequisite: MA 513

Basic equations of ideal fluid flow; potential and stream functions; vortex dynamics; body forces due to flow fields, methods of singularities in two-dimensional flows; analytical determination of potential functions; conformal transformations; free-streamline flows. Messrs. C. M. Chang, Edwards, Sorrell

EM 505 MECHANICS OF VISCOUS FLUIDS I 3(3-0) S
Prerequisite: EM 304
Corequisite: MA 532

Equations of motion of a viscous fluid (Navier-Stokes Equations); general properties of the Navier-Stokes equations; some exact solutions of the Navier-Stokes equations; boundary layer equations; some approximate methods of

solution of the boundary layer equations; laminar boundary layers in axisymmetric and three-dimensional flows; unsteady laminar boundary layers.
Messrs. Edwards, Sorrell

EM 506 MECHANICS OF COMPRESSIBLE FLUIDS I 3(3-0) S
Prerequisites: EM 304, MAE 302
Corequisite: MA 532

Introduction to the flow of a compressible fluid: thermodynamics and one-dimensional energy equation for a compressible gas. Acoustics, normal shock waves and expansion waves, shock tube theory, general one-dimensional flow and flow in ducts and channels. Messrs. C. M. Chang, Sorrell

EM 507 SYSTEMS ANALYSIS 3(3-0) F
Prerequisites: EM 301, EM 303, MA 511

A study of the analysis of dynamical systems. With the employment of state variable techniques, the qualitative features and fundamental concepts of the engineering system are examined. Messrs. Gogolewski, McDonald

EM 508 SYSTEMS SYNTHESIS 3(3-0) S
Prerequisite: EM 507

A study of the synthesis of dynamical systems. The modern approach to systems synthesis is employed through the application of variational principles and optimization techniques. Messrs. Gogolewski, McDonald

EM 509 SPACE MECHANICS I 3(3-0) F
Prerequisites: EM 302, EM 304
Corequisite: MA 511

The application of mechanics to the analysis and design of orbits and trajectories. Trajectory computation and optimization; space maneuvers; reentry trajectories; interplanetary guidance. Messrs. Clayton, Maday

EM 510 SPACE MECHANICS II 3(3-0) F
Prerequisites: EM 509, MA 511

Continuation EM 509. The analysis and design of guidance systems. Basic sensing devices; the characteristics of an inertial space; the theory of stabilized platforms; terrestrial inertial guidance. Messrs. Clayton, Maday

EM 511 THEORY OF PLATES AND SHELLS 3(3 0) F
Prerequisites: EM 301, MA 511

Bending theory of thin plates; geometry of surfaces and stresses in shells. Various methods of analysis are discussed and illustrated by problems of practical interest. Messrs. Bingham, Clayton, Gurley

EM 521, 522 PROPERTIES OF SOLIDS I, II 3(3 0) F
Prerequisites: EM 307, MAT 301, PY 413

Atomic and molecular principles are applied toward an introductory understanding of macroscopic material properties. The concept of the grand canonical ensemble average of atomic behavior is employed to unify the characterization and interrelationships of material properties. Finally, phenomenological behaviors and coupled effects are described within the continuum concept. Mr. Horie

EM 551 ADVANCED STRENGTH OF MATERIALS 3(3-0) F
Prerequisite: EM 301

Stresses and strains at a point; rosette analysis; stress theories, stress concentration and fatigue; plasticity; inelastic, composite and curved beams; prestress

energy methods; shear deflections; buckling problems and column design; and membrane stresses in shells. Mr. Gurley

EM 552 ELASTIC STABILITY 3(3-0) S
Prerequisites: EM 551, MA 301, MA 405

A study of elastic and plastic stability. The stability criterion as a determinant. The energy method and the theorem of stationary potential energy. The solution of buckling problems by finite differences and the calculus of variations. The application of successive approximations to stability problems. Optimization applied to problems of aeroelastic and civil engineering structures. Mr. Gurley

EM 555 DYNAMICS I 3(3-0) F
Prerequisites: EM 301, MA 405

The theory of vibrations from the Lagrangian formulation of the equations of motion. Free and forced vibrations with and without damping, multiple degrees of freedom, coupled motion, normal mode vibrations, wave propagation in solid bodies.
Messrs. Clayton, Gogolewski

EM 556 DYNAMICS II 3(3-0) S
Prerequisites: EM 301, MA 405

The dynamics of particles and rigid bodies by the use of formulations of the laws of mechanics due to Newton, Euler, Lagrange and Hamilton. Accelerated reference frames, constraints, Euler's angles, the spinning top, the gyroscope, precession, stability, phase space and nonlinear oscillatory motion.
Messrs. Clayton, Gogolewski

EM 590 (PHI 590, REL 590) TECHNOLOGY AND HUMAN VALUES 3(3-0) F
Prerequisites: A baccalaureate degree in engineering, liberal arts, science or social science; or, for advanced undergraduates, two or more courses such as HI 341, SS 301, 302, SS 401, or six hours in philosophy

An exploration from two or more disciplinary perspectives (notably those of of ethical theory and cybernetic information theory) the range of ways of conceptualizing the relationship between the technologies of a society and the values of that society, and in areas of particular interest to students, a detailed analysis of contemporary instances of the interrelation of technology and human values.
Messrs. McDonald, Shriver

FOR GRADUATES ONLY

EM 601, 602 UNIFYING CONCEPTS IN MECHANICS I, II 3(3-0) FS
Prerequisite: PY 601

Generalized treatment of the fundamental equations and boundary value problems of continuous and noncontinuous media. Use is made of contemporary developments in irreversible thermodynamics, statistical mechanics and electro-dynamics to provide a unified foundation for the development of principles governing the dynamic and thermodynamic behavior of elastic, plastic and viscoelastic solids, viscous fluids and rheological media. Messrs. T. S. Chang, McDonald

EM 603 THEORY OF ELASTICITY II 3(3-0) S
Prerequisite: EM 503
Corequisite: MA 513

An extension of EM 503 to include the Cauchy Integral methods for plane problems, three-dimensional problems, variational methods and the use of numerical methods. Messrs. Ely, T. E. Smith

EM 604 THEORY OF PLASTICITY 3(3-0) S
Prerequisite: EM 503

Analytical models are developed to represent the behavior of deformable solids in the plastic regime. Conditions of yielding and fracture which initiate and terminate plastic behavior are studied, with the special stress-strain relationships necessary in plasticity. The hyperbolic equations of slipline fields characteristic of plane strain theory are developed. Messrs. Douglas, Horie

EM 605, 606 (MAS 605, 606; OY 605, 606)
ADVANCED GEOPHYSICAL FLUID MECHANICS I, II 3(3 0) FS
(See physical oceanography, page 249.)

EM 611 MECHANICS OF COMPRESSIBLE FLUIDS II 3 S
Prerequisite: EM 506

A continuation of EM 506. Linearized theory of two- and three-dimensional supersonic flow past bodies. Oblique shock waves and method of characteristics for two-dimensional supersonic flow. Unsteady supersonic flow, and compressible flow with viscosity and heat transfer. Messrs. C. M. Chang, Sorrell

EM 612 MECHANICS OF VISCOUS FLUIDS II 3 F
Prerequisite: EM 505

Continuation of EM 505, phenomenological theories of turbulence, turbulent flow in ducts and pipes, turbulent boundary layer with and without pressure gradient, compressible boundary layer, boundary layer control and free viscous flow. Messrs. Sorrell, Edwards

EM 613, 614 (MAS 613, 614; OY 613, 614)
PERTURBATION METHOD IN FLUID MECHANICS I, II 3(3 0) FS
(See physical oceanography, page 249.)

EM 621 PROPERTIES OF MATERIALS AT LOW TEMPERATURES 3(3-0) FS
Prerequisites: EM 301, EM 521 or equivalent

Recent developments in low-temperature theory and applications of materials are presented starting with the theory of atomic processes which govern low temperature behavior. A study of the current models of the dominant physical processes at low temperatures is applied to mechanical, thermal and electrical behavior, including superconductivity and superfluidity. Results are applied toward prediction and correlation of properties at higher temperatures where the governing physical processes are more interrelated. Mr. Horie

EM 631, 632 (OR 631, 632) VARIATIONAL METHODS IN
OPTIMIZATION TECHNIQUES I, II 3(3-0) FS
(See operations research, page 246.)

EM 641 OPTICAL MECHANICS 3(2-3) S
Prerequisite: EM 312 or MAE 516

Concepts of crystal optics applied to continua deformed statically or dynamically by mechanical or thermal loading; optical interference and its use as a measuring technique of absolute and relative retardations in various types of interferometers; relative retardation measurements; deformation measurements with diffraction gratings; Moire (mechanical) interference measurements.
Mr. Bingham

EM 656 NONLINEAR VIBRATIONS 3(3-0) FS
Prerequisite: EM 555

Free and forced vibrations of systems with nonlinear restoring forces and

self sustained oscillations. Approximation techniques applied to nonlinear differential equations. Comparison with exact solutions when possible. Emphasis placed on understanding properties unique to nonlinear systems. Mr. Clayton

EM 695 EXPERIMENTAL METHODS IN MECHANICS 3(2-3) S
Prerequisite: Consent of instructor

A study of specialized experimental techniques utilized in contemporary research in the areas of mechanics. Messrs. Bingham, Douglas, Edwards

EM 697 SEMINAR IN MECHANICS 1(1 0) FS
Prerequisites: Graduate standing, consent of adviser

The discussion and development of theory relating to contemporary research in the frontier areas of mechanics. Messrs. T. S. Chang, Douglas

EM 698 SPECIAL TOPICS IN MECHANICS Credits Arranged

The study, by small groups of graduate students under the direction of members of the faculty, of topics of particular interest in various advanced phases of mechanics. Graduate Staff

EM 699 RESEARCH IN MECHANICS Credits Arranged

Individual research in the field mechanics. Graduate Staff

English

GRADUATE FACULTY

Professor LARRY S. CHAMPION, *Head*
Professors. HENDERSON G. KINCHELOE, BENJAMIN G. KOONCE, JR., FRANK H. MOORE, GUY OWEN, JR., CHARLES A. PARKER, WILLIAM B. TOOLE, III; *Professors Emeritus:* LODWICK C. HARTLEY, RICHARD G. WALSER; *Associate Professors:* LEONIDAS J. BETTS, JR., PHILIP E. BLANK, JR., EDMUND P. DANDRIDGE, JR., JACK D. DURANT, MAX HALPEREN, ALBERT S. KNOWLES, JR., WALTER E. MEYERS, ROBERT B. WHITE, JR., PORTER WILLIAMS, JR.; *Assistant Professors:* MICHAEL S. REYNOLDS, ALLEN F. STEIN, THOMAS N. WALTERS

The Department of English offers instruction leading to the Master of Arts degree with specialization in English and American literature. The program is designed either to provide the student with a terminal course of study or to serve as the first year toward a doctorate.

A minimum of thirty semester hours of graduate credit is required, though the program may be expanded to meet individual student situations.

Assistantships for promising students are available. These students will take ENG 504 in the fall semester and devote half time in the fall and spring semesters to the teaching of courses in freshman composition under supervision.

FOR GRADUATES AND ADVANCED UNDERGRADUATES

ENG 504 PROBLEMS IN COLLEGE COMPOSITION 3(3-0) F
Prerequisite: Consent of instructor or graduate standing

Directed study of the development of rhetorical skills in composition in classroom situations. Messrs. Betts, Walters

ENG 524 MODERN ENGLISH USAGE 3(3-0) S
Prerequisite: Consent of instructor or graduate standing

An intensive study of English grammar, with attention to new developments in structural linguistics and with emphasis on current usage. Mr. Meyers

ENG 526 HISTORY OF THE ENGLISH LANGUAGE 3(3-0) FS
Prerequisite: Consent of instructor or graduate standing

A survey of the growth and development of the language from its Indo European beginnings to the present. Mr. Meyers

ENG 561 MILTON 3(3 0) S
Prerequisite: ENG 261 or equivalent

An intensive reading of Milton with attention to background materials in the history and culture of seventeenth-century England. Messrs. Moore, White

ENG 575 SOUTHERN WRITERS 3(3 0) S
Prerequisite: ENG 266 or equivalent

A survey of the particular contribution of the South to American literature, with intensive study of selected major figures. Mr. Kincheloe

ENG 578 ENGLISH DRAMA TO 1642 3(3-0) F
Prerequisite: ENG 261 or equivalent

Intensive study of the English drama from its liturgical beginnings to the closing of the theaters, excluding Shakespeare. Messrs. Champion, Toole

ENG 579 ENGLISH DRAMA OF THE RESTORATION AND EIGHTEENTH CENTURY 3(3 0) S
Prerequisite: ENG 261 or equivalent

Intensive study of the English drama from 1660 to 1800. Mr. Durant

ENG 590 LITERARY CRITICISM 3(3 0) S

Prerequisite: ENG 261 or equivalent

An examination of the critical process as it leads to the definition and analysis of literature, together with attention to the main literary traditions and conventions. Messrs. Halperen, Williams

FOR GRADUATES ONLY

ENG 608 BIBLIOGRAPHY AND METHODOLOGY 3(3-0) FS
Prerequisite: Graduate standing

An investigation of the materials of literary research and scholarship; an introduction to varying scholarly approaches to literary problems leading to development of the student's ability to evaluate and use with discrimination the work of scholars in his field. Messrs. Meyers, White

ENG 610 MIDDLE ENGLISH LITERATURE 3(3-0) F
Prerequisite: Graduate standing

A study of major works of medieval English literature (exclusive of Chaucer) in the light of dominant intellectual and artistic traditions; emphasis on four works: *Piers Plowman*, *Pearl*, *Sir Gawain and the Green Knight*, and Malory's *Morte Darthur*. (Offered in 1971 and 1973.) Mr. Koonce

ENG 615 AMERICAN LITERATURE OF THE COLONIAL PERIOD 3(3-0) F
Prerequisite: Graduate standing

A study of American literature and thought from the beginnings to the adoption of the Constitution. (Offered in 1972 and 1974.) Mr. Owen

ENG 620 16TH CENTURY NON DRAMATIC ENGLISH LITERATURE 3(3-0) F
Prerequisite: Graduate standing

A detailed survey of non-dramatic prose and verse of the sixteenth century against the background of Humanism with the consequent assimilation of classical and continental literary subjects and forms. Mr. Blank

ENG 630 17TH CENTURY ENGLISH LITERATURE 3(3 0) S
Prerequisite: Graduate standing

A close examination of the literature of England from 1600 to 1700 with emphasis on major literary figures and movements, the development of important literary forms and genres, and the intimate relationship between the literature of this period and its philosophical, political and theological backgrounds.
Messrs. Moore, White

ENG 650 19TH-CENTURY ENGLISH LITERATURE: THE ROMANTIC PERIOD 3(3 0) F
Prerequisite: Graduate standing

A detailed study of the six major romantic poets Blake, Wordsworth, Coleridge, Byron, Shelley and Keats; some attention as well to the political, social and literary background and to a few minor writers and critics. Mr. Williams

ENG 651 STUDIES IN CHAUCER 3(3-0) F
Prerequisite: ENG 451 or equivalent

An intensive study of the Chaucer canon requiring independent research.
Mr. Koonce

ENG 655 19TH-CENTURY AMERICAN LITERATURE: THE ROMANTIC PERIOD 3(3-0) F
Prerequisite: Graduate standing

A study of the selected works of Poe, Hawthorne, Melville, Emerson and Thoreau, with emphasis on their varied contributions to the literature and thought of the American romantic movement. Mr. Stein

ENG 658 STUDIES IN SHAKESPEARE: THE TRAGEDIES 3(3-0) F
Prerequisite: Graduate standing

An intensive study textual and critical of Shakespeare's tragedies.
Messrs. Champion, Toole

ENG 659 STUDIES IN SHAKESPEARE: THE COMEDIES 3(3 0) S

Prerequisite: Graduate standing

An intensive study textual and critical of Shakespeare's comedies.
Messrs. Champion, Toole

ENG 660 19TH CENTURY ENGLISH LITERATURE: THE VICTORIAN PERIOD 3(3-0) S

Prerequisite: Graduate standing

Studies in the literature of Victorian England: 1837 1901; the major writers, movements and questions in their historical contexts, religious, political and aesthetic. Mr. Williams

ENG 662 18TH CENTURY ENGLISH LITERATURE 3(3 0) F
Prerequisite: Graduate standing

The major figures in English literature between 1660 and 1790 against the background of social, cultural and religious change. Messrs. Durant, White

ENG 665 19TH CENTURY AMERICAN LITERATURE: THE PERIOD OF REALISM AND NATURALISM 3(3-0) S
Prerequisite: Graduate standing

Concentration on Whitman, Dickinson, Twain, James and Dreiser, with briefer attention to Howells, Crane, Norris, and other realists and naturalists. Mr. Stein

ENG 670A 20TH CENTURY BRITISH LITERATURE (PROSE) 3(3-0) S
Prerequisite: Graduate standing

An examination of the works of the major British writers and literary movements of this century and their historical context, religious, political and aesthetic. (Offered in 1972 and 1974.) Messrs. Halperen, Knowles

ENG 670B 20TH-CENTURY BRITISH LITERATURE (POETRY) 3(3 0) S
Prerequisite: Graduate standing

The development of English poetry from the rebellion against Victorian and Pre-Raphaelite verse to the present post-war scene; special attention to Hardy, Yeats, Eliot, Auden and Thomas. (Offered in 1973 and 1975.)
Messrs. Halperen, Owen

ENG 675A 20TH CENTURY AMERICAN LITERATURE (PROSE) 3(3 0) F
Prerequisite: Graduate standing

An examination of representative American writers of the novel and short fiction. (Offered in 1972 and 1974.) Messrs. Knowles, Owen

ENG 675B 20TH-CENTURY AMERICAN LITERATURE (POETRY) 3(3-0) F
Prerequisite: Graduate standing

The development of modern American poetry from the rebellion against the romantic and genteel verse of the 1890's; special attention to Robinson, Frost, Pound, Williams, Stevens and Ransom. (Offered in 1971 and 1973.)
Messrs. Halperen, Owen

ENG 680A 20TH CENTURY DRAMA (BRITISH) 3(3 0) S
Prerequisite: Graduate standing

A survey of modern British drama from its beginnings at the turn of the century to the present. (Offered in 1972 and 1974.) Messrs. Halperen, Knowles

ENG 680B 20TH-CENTURY DRAMA (AMERICAN) 3(3-0) S
Prerequisite: Graduate standing

A survey of modern American drama centering on major figures. (Offered in 1973 and 1975.) Messrs. Halperen, Knowles

ENG 692 SPECIAL TOPICS IN AMERICAN LITERATURE 3(3-0) FS
Prerequisite: Consent of seminar chairman

An intensive study, involving independent research and centering on some limited topic from American literature. Fall, 1972, Black American literature (Barrax); spring, 1973, Henry James (Stein); fall, 1973, Ezra Pound (Halperen); spring, 1974, Hemingway (Knowles). Graduate Staff

ENG 693 SPECIAL TOPICS IN ENGLISH LITERATURE 3(3-0) FS
Prerequisite: Consent of seminar chairman

An intensive study, involving independent research and centering on some limited topic from English literature. Fall, 1972, James Joyce (Halperen); spring, 1973, Spenser (Blank); fall, 1973, linguistics and literary criticism (Meyers); spring, 1974, Dryden (F. Moore). Graduate Staff

ENG 699 RESEARCH IN LITERATURE (THESIS) Credits Arranged FS
Prerequisite: Consent of graduate adviser

Independent investigation of an advanced literary or linguistic problem leading to the writing of a master's thesis. Graduate Staff

Entomology

GRADUATE FACULTY

Professor KENNETH L. KNIGHT, *Head*
Professors: RICHARD C. AXTELL, CHARLES H. BRETT, WILLIAM V. CAMPBELL, MAURICE H. FARRIER, FRANK E. GUTHRIE, ERNEST HODGSON, WALTER J. MISTRIC, JR., HERBERT H. NEUNZIG, ROBERT L. RABB, THOMAS J. SHEETS, CLYDE F. SMITH, DAVID A. YOUNG, JR.; *Professor Emeritus:* THEODORE B. MITCHELL; *Adjunct Professors:* LAWRENCE FISHBEIN, JAMES R. FOUTS, LOUISE M. RUSSELL, CURTIS W. SABROSKY, REECE I. SAILER; *Extension Professors:* ROBERT L. ROBERTSON, GERALD T. WEEKMAN; *Associate Professors:* WAYNE M. BROOKS, WALTER C. DAUTERMAN, HARRY B. MOORE, GEORGE C. ROCK, CHARLES G. WRIGHT, ROBERT T. YAMAMOTO; *Adjunct Associate Professors:* ALBERT L. CHASSON, EDGAR W. CLARK; *Assistant Professor:* JULIUS R. BRADLEY, JR.; *Extension Assistant Professor:* KENNETH A. SORENSEN

The Department of Entomology offers graduate training leading to the Master of Entomology, Master of Science and Doctor of Philosophy degrees. Major areas of specialization are: acarology, agricultural entomology, behavior, biochemistry and toxicology, ecology, invertebrate pathology, medical and veterinary entomology, nutrition, pesticide analysis, pest management and taxonomy.

The department is particularly well qualified to provide intensive training in areas requiring an interdisciplinary approach since the departmental staff includes members of the faculties of physiology, cell biology and ecology.

The extensive program of research, supported by federal granting agencies, industry and the University, provides opportunities for graduate training through actual participation in research.

Opportunities exist for training in both applied and fundamental phases of entomology and invertebrate biology. Population management concepts are emphasized in the applied entomology and pest management programs. The applied phases are influenced by the state's agriculture, in which tobacco, cotton, peanuts, fruit, vegetables, livestock and forestry are important components. The rapidly expanding tourist industry and the diverse habitats of the state, extending from the mountains to the sea, provide unique opportunities for research on insects and related arthropods affecting man. A cooperative arrangement with the School of Forest Resources provides majors in forest entomology. The program in medical and veterinary entomology includes both applied and fundamental research and provides the opportunity for training at the School of Public Health, Chapel Hill.

Fundamental areas of particular interest are biochemistry and toxicology, physiology and behavior, and taxonomy. The program in biochemistry and toxicology is interdepartmental involving faculty from the departments of biochemistry, crop science, entomology, statistics and genetics. Taxonomy is particularly strong in the aphids, leafhoppers, mites and mosquitoes. Invertebrate pathology emphasizes protozoan diseases. Ecology, population dynamics, behavior and nutrition are emphasized in several programs.

The departmental research and training programs are well supported by a complex of modern facilities including: a pesticide residue analysis laboratory, pesticide research laboratory, comparative biochemistry and toxicology laboratories, a behavior laboratory, insect rearing rooms, greenhouses and field stations. An adjacent phytotron or bioclimatic facility provides a unique opportunity for ecological and behavioral studies under controlled conditions. Ultrastructural investigations are conducted in the School of Agriculture and Life Sciences' Electron Microscope Center. Extensive nuclear reactor and computer facilities and statistical services are available on campus.

The student is given wide latitude in the selection of his advisory committee and choice of major and minor subject areas. Stress is placed on development of independent thought, broad training in fundamentals and mastery of investigative techniques.

FOR ADVANCED UNDERGRADUATES

ENT 401 (ZO 401) BIBLIOGRAPHIC RESEARCH IN BIOLOGY 1(1 0) F

A general course intended to acquaint students with literature problems of the scientist, mechanics of the library book classifications, bibliographies, abstract journals, taxonomic indexes and preparation of scientific papers in agriculture, forestry, biology and their subdivisions. (Offered fall 1972 73 and alternate years.)

Mr. Farrier

FOR GRADUATES AND ADVANCED UNDERGRADUATES

ENT 502 INSECT DIVERSITY 4(2-4) F
Prerequisite: Twelve hours of biology

An introduction to the external morphology of insects and a survey of the biology and identification of immature and adult insects. Evolutionary relationships of insects and other arthropods, speciation, insect zoogeography, nomenclature, and classical and recent approaches to systematics are also considered.

Messrs. Axtell, Neunzig, Rabb, Young

ENT 503 FUNCTIONAL SYSTEMS OF INSECTS 4(2-6) S
Prerequisites: Twelve hours of biology, nine hours of chemistry, three hours of biochemistry, ENT 301 or equivalent

Structure and morphological variations of organ systems in insects including considerations of their histology and function. Sensory and general physiology will then lead into basic elements of insect orientation and behavior.

Messrs. Campbell, Hodgson, Yamamoto

ENT 504 INSECT MORPHOLOGY 3(1-4) F
Prerequisite: ENT 502

Concerned with external morphology, primary and comparative phases, with emphasis on knowledge and techniques which can be applied to specific problems. (Offered fall 1973 74 and alternate years.) Mr. Young

ENT 511 SYSTEMATIC ENTOMOLOGY 3(1-4) F
Prerequisite: ENT 301 or ENT 312 or equivalent

A somewhat detailed survey of the orders and families of insects, designed to acquaint the student with those groups and develop in the student some ability in the use of the taxonomic literature. (Offered fall 1972-73 and alternate years.)
Mr. Young

ENT 520 INSECT PATHOLOGY 3(2-3) S
Prerequisites: Introductory entomology and introductory microbiology

A treatment of the noninfectious and infectious diseases of insects, the etiologi cal agents and infectious processes involved, immunological responses and applications. (Offered spring 1972 73 and alternate years.) Mr. Brooks

ENT 531 INSECT ECOLOGY 3(2-2) F
Prerequisite: ENT 502

The environmental relations of insects, including insect development, habits, distribution and abundance. (Offered fall 1973-74 and alternate years.) Mr. Rabb

ENT 541 IMMATURE INSECTS 2(1 3) F
Prerequisite: ENT 502 or equivalent

An advanced study of the immature stages of selected orders of insects with emphasis on generic and specific taxa. Primary consideration is given to the larval stage, but a brief treatment of eggs and pupae is also included. (Offered fall 1972 73 and alternate years.) Mr. Neunzig

ENT 542 ACAROLOGY 3(2-3) S
Prerequisite: ENT 301 or ENT 312 or ZO 201

A systematic survey of the mites and ticks with emphasis on identification, biology and control of the more common and economic forms attacking material, plants and animals including man. (Offered spring 1972-73 and alternate years.)
Mr. Farrier

ENT 550 FUNDAMENTALS OF INSECT CONTROL 3(2-2) F
Prerequisites: ENT 312 or ENT 301 and senior standing

The course is divided into two phases. The first deals with the basic causes of insect problems, an evaluation of the biological and economic aspects of insect attack and the fundamental methods employed in insect control. The second part deals with the critical chemical, physical and biological properties of compounds used for insect control. The material presented in the course is directed toward obtaining fundamental knowledge of the scientific principles underlying modern methods of protection of food, clothing, shelter and health from arthropods. Mr. Guthrie

ENT 562 AGRICULTURAL ENTOMOLOGY 3(2-3) S
Prerequisite: ENT 301 or ENT 312

A study of the taxonomy, biology and ecology of beneficial and injurious insects and arachnids of agricultural crops. Advantages and limitations of the advanced concepts for controlling insect and mite populations on different crops will be emphasized. (Offered spring 1972-1973 and alternate years.) Messrs. Bradley, Rock

ENT 575 (PHY 575, ZO 575) PHYSIOLOGY OF INVERTEBRATES 3(3-0)F
(See physiology, page 258.)

ENT 582 (ZO 582) MEDICAL AND VETERINARY ENTOMOLOGY 3(2-3) S
Prerequisites: ENT 301 or ENT 312 and ZO 315 or equivalent

A study of the morphology, taxonomy, biology and control of the arthropod

parasites and disease vectors of man and animals. The ecology and behavior of vectors in relation to disease transmission and control will be emphasized. (Offered spring 1973-74 and alternate years.) Mr. Axtell

ENT 590 SPECIAL PROBLEMS Credits Arranged FS
Prerequisite: Consent of instructor

Original research on special problems in entomology not related to a thesis problem, but designed to provide experience and training in research.
Graduate Staff

FOR GRADUATES ONLY

ENT 602 PRINCIPLES OF TAXONOMY 3(1 4) S
Prerequisite: ENT 511

A course introducing the methods and tools used in animal taxonomy, designed to promote a better understanding of taxonomic literature and provide a foundation for taxonomic research. (Offered spring 1973-74 and alternate years.) Mr. Young

ENT 611 BIOCHEMISTRY OF INSECTS 3(3 0) F
Prerequisite: BCH 551 or equivalent

The biochemistry of insects will be considered with primary emphasis on intermediate metabolism. Aspects in which insects show specialization will be treated in greater detail. The comparative treatment used necessitates some consideration of other animal groups. (Offered fall 1972-73 and alternate years.)
Mr. Hodgson

ENT 622 INSECT TOXICOLOGY 3(2 3) S
Prerequisites: ENT 550, BCH 551 or equivalent

The relation of chemical structure to insect toxicity, the mode of action of toxicants used to kill insects, the metabolism of insecticides in plant and animal systems, the selectivity within the cholinesterase inhibitors and other selective mechanisms and the analysis of insecticide residues will be discussed. (Offered spring 1973-74 and alternate years.) Messrs. Dauterman, Guthrie

ENT 690 SEMINAR 1(1-0) FS
Prerequisite: Graduate standing in entomology or closely allied fields

Discussion of entomological topics selected and assigned by seminar chairman.
Graduate Staff

ENT 699 RESEARCH Credits Arranged FS
Prerequisite: Graduate standing

Original research in connection with thesis problem in entomology.
Graduate Staff

Fiber and Polymer Science

ASSOCIATED GRADUATE FACULTY

Professors: JOHN F. BOGDAN, KENNETH S. CAMPBELL, DAVID M. CATES, DAVID W. CHANEY, RICHARD D. GILBERT, GEORGE GOLDFINGER, DAME S. HAMBY, SOLOMON P. HERSH, HENRY A. RUTHERFORD, VIVIAN T. STANNETT, ROBERT W. WORK, AND CARL F. ZOROWSKI; *Adjunct Professors:* HERMAN F. MARK, ARNOLD M. SOOKNE; *Associate Professors:* JOHN A. CUCULO, A. H. M. EL-

SHIEKH, T. WALLER GEORGE, THOMAS H. GUION, PETER R. LORD, RALPH MCGREGOR, AND THEODORE G. ROCHOW; *Research Associate:* CARL E. BRYAN; *Assistant Professors:* PETER BROWN, RAYMOND E. FORNES, BHUPENDER S. GUPTA, MICHAEL H. THEIL, WILLIAM K. WALSH

THE PROGRAM

Fiber and Polymer Science is a multidisciplinary program bringing together the fundamental disciplines of mathematics, chemistry and physics and the application of engineering principles to the common objective of developing an independent scholar versed in the field of fiber materials science. The program is administered by the School of Textiles and leads to the degree of Doctor of Philosophy. Broadly speaking, polymers form the base of all living substances, both vegetable and animal. The linear or fibrous sub division of these provide strength to the former and mobility to the latter. Additionally, much of the significant technological and industrial advancement of this century has depended upon the synthesis and application of new polymers and fibers to meet the needs of society. Not the least revolutionary of these has been the development and growth in the field of man-made fibers. The impact of these on the textile and materials industries and in turn upon the habits and living standards of the people of this generation has been dramatic.

The program, necessarily broad in scope, is concerned not only with the basic polymeric materials themselves, but also with the fibers and structures into which these materials can be fashioned and the processes by which they can be changed. This broad base brings to the program its principal strength and permits a wide range of specializations. The candidate is expected to penetrate deeply into one field of specialization and to acquire a reasonable perspective concerning the other relevant academic fields. Generally these specialities encompass the areas of polymer chemistry and synthesis; fiber and polymer physics and physical chemistry; and textile mechanics and technology, including composite structures.

The student's research is based upon the chosen area of specialization and constitutes his contribution of new knowledge to society. With such a background he is prepared to enter a career of teaching and research in a university, to engage in research and development upon polymeric and fibrous materials in industry or to locate in any of the many governmental laboratories. Not the least among the opportunities available will be those presented by the several organizations of the man made fiber industry (already very advanced and sophisticated); by the evolving field of structural materials based on fiber-polymer composites; and by the presently emerging activities of the primary textile industry, wherein future research is accepted as imperative for continued growth.

RESEARCH ACTIVITIES, FACILITIES AND EQUIPMENT

Current research activities emphasize studies of polymer crystallization phenomena, fundamental studies of the ultimate nature and the formation of man-made fibers and their properties; the physics, chemistry and utility of yarn and fabric structures and their properties; electrical, frictional and mechanical properties of fibers and yarns, water pollution and noise abatement, polymer-solvent interactions, sorption and diffusion processes, mechanism of reactions with fibrous substrates, modification of fibrous polymers by radiation, thermal properties of polymers, novel processes associated with current developments in materials and equipment, the physical chemistry of dyeing, and color physics.

Ample laboratory space is available in the Nelson Building and David Clark Laboratories. There are a number of specialized laboratories well equipped to support the doctoral investigations. Some of the laboratories and services of particular specialization include the following: radiation laboratory cobalt 60 source, polymer synthesis laboratory, polymer crystallization laboratory, polymer extrusion laboratory (experimental single position units for melt-spinning, dry spinning and drawing), color instrumentation laboratory, microscopy laboratory, fiber physics laboratory, fiber and polymer characterization laboratory, physical testing laboratory, nuclear magnetic resonance laboratory, noise laboratory, dark room facilities, electronics and instrumentation shop, machine shop, extensive pilot finishing and dyeing equipment, and extensive conventional and nonconventional textile processing equipment. The Burlington Textiles Library in the Nelson Building houses one of the finest and most complete collections of polymer literature in the country. The collection includes a total of 11,200 bound volumes, 6,000 of which are books; currently over 300 periodicals are received.

In addition other facilities and research equipment are available in cooperating departments on campus which may be used in fiber and polymer science research programs.

ADMISSION

Students majoring in the physical sciences, mathematics, textiles or engineering and having at least a "B" grade in their undergraduate major will normally qualify for admission. Students interested in a graduate program in fiber and polymer science are encouraged to complete the necessary prerequisites for the general courses prior to entrance in graduate school.

DEGREE REQUIREMENTS—DOCTOR OF PHILOSOPHY

An advisory committee chaired by a member of the fiber and polymer science faculty is formed as soon as possible in order to develop with the student a plan of study designed to enable him to acquire the comprehensive knowledge required to successfully complete the qualifying examinations. Currently these examinations are offered in the form of a cumulative system consisting of a set of common written examinations taken by all candidates covering the broad aspects of fiber and polymer science followed by an individualized examination of the student's specialized interest. One unique feature of the cumulative examination is a special question devoted to a current research topic announced in advance in which the relevant literature is critically reviewed and analyzed. By use of this technique, the student becomes aware of and participates in the application of the many disciplines which contribute to the unifying concepts of fiber and polymer science.

In accordance with regulations of the Graduate School, there are no definite requirements in credit hours for the Doctor of Philosophy degree. The complete program of study developed by the advisory committee and the student is designed to encompass the student's own special interests. While each plan would be specifically tailored for the individual student, the committee will be guided by the spirit of the need to compose a coherent program that enhances the student's professional development and excellence in research. Normally a program to achieve these goals can be realized by taking 18 to 21 credit hours of graduate level work within the School of Textiles. This is usually supplemented with an equal number of hours in a revelant minor or an interdisciplinary minor distributed over two or three appropriate fields such as chemistry, physics, mathematics, chemical engineering, statistics or engineering mechanics.

Requirements for the minor, the dissertation, languages, comprehensive examination, admission to candidacy, residence and final oral examinations are specified in the regulations of the Graduate School.

DOCTOR OF PHILOSOPHY MINOR

Ph.D. candidates wishing to designate a named minor in fiber and polymer science will be required to take and pass the common part of the cumulative examination.

Because of the broad scope and interconnected character of the field, split minors in the Fiber and Polymer Science Program administered by the School of Textiles are generally regarded as undesirable and are discouraged. The Departments of Textile Chemistry and Textile Technology, however, offer minors in various aspects of textile and fiber technology, textile chemistry, and polymer chemistry.

MASTER OF SCIENCE MINOR

A listed minor in fiber and polymer science will not be permitted. Minors are available, however, in textile chemistry and textile technology.

Communications concerning the Fiber and Polymer Science Program should be directed to the Chairman of the Graduate Studies Committee, School of Textiles, North Carolina State University.

COURSE OFFERINGS

(See departmental listing for descriptions)

GENERAL COURSES

TC 461 (CH 461)	CHEMISTRY OF FIBERS
TC 504	FIBER FORMATION THEORY AND PRACTICE
TC 562 (CH 562)	PHYSICAL CHEMISTRY OF HIGH POLYMERS—BULK PROPERTIES
TX 465	MECHANICS OF YARN FORMATION
TX 561	MECHANICAL AND RHEOLOGICAL PROPERTIES OF FIBROUS MATERIAL

COURSES IN AREAS OF SPECIALIZATION

Polymer Chemistry and Synthesis

TC 561	ORGANIC CHEMISTRY OF HIGH POLYMERS
TC 671 (CHE 671)	SPECIAL TOPICS IN POLYMER SCIENCE

Polymer Physics and Physical Chemistry

TC 505	THEORY OF DYEING
TC 662	PHYSICAL CHEMISTRY OF HIGH POLYMERS—SOLUTION PROPERTIES
TX 500	ADVANCED MICROSCOPY
TX 560	STRUCTURAL AND PHYSICAL PROPERTIES OF FIBERS
TX 691 (TC 691)	SPECIAL TOPICS IN FIBER SCIENCE
T 501	RESINOGRAPHY
CHE 569 (TC 569)	POLYMERS, SURFACTANTS, AND COLLOIDAL MATERIALS
CHE 669 (TC 669)	DIFFUSION IN POLYMERS

Fiber Mechanics and Technology

TX 550	FABRIC ANALYTICS
TX 591	SPECIAL TOPICS
TX 601	STAPLE FIBER STRUCTURES
TX 602	STAPLE FIBER STRUCTURES II
TX 663 (MAE 663)	MECHANICS OF TWISTED STRUCTURES
TX 664 (MAE 664)	MECHANICS OF FABRIC STRUCTURES

Food Science

GRADUATE FACULTY

Professor WILLIAM M. ROBERTS, *Head*

Professors: LEONARD W. AURAND, THOMAS N. BLUMER, HARRIS B. CRAIG, MAURICE W. HOOVER, MARVIN L. SPECK, *Graduate Administrator,* FREDERICK G. WARREN; *Extension Professor:* ELOISE S. COFER; *Professors USDA:* THOMAS A. BELL, JOHN L. ETCHELLS, ALBERT E. PURCELL; *Professor Emeritus:* IVAN D. JONES; *Associate Professors:* DONALD D. HAMANN, VICTOR A. JONES, HAROLD E. SWAISGOOD, NEIL B. WEBB; *Extension Associate Professor:* FRED R. TARVER, JR.; *Associate Professors USDA:* HENRY P. FLEMING, WILLIAM M. WALTER, JR.; *Assistant Professors:* HERSHELL R. BALL, JR., DANIEL E. CARROLL, JR., STANLEY E. GILLILAND, ARTHUR P. HANSEN, BOBBY R. JOHNSON; *Adjunct Assistant Professors:* WILLIAM Y. COBB, RAGHUNATH S. DAHIYA

Programs of study leading to the Master of Science and Doctor of Philosophy degrees are offered for students who pursue graduate studies in the field of food science. In addition, the Master of Food Science degree can be earned by students who do not plan further graduate study and who wish to de-emphasize research in their graduate study. The programs are supervised by members of the graduate faculty in the Department of Food Science with corollary training in the biological and physical sciences. The student has the opportunity to develop and apply concepts in the various areas of food science based on fundamental principles in the physical and biological sciences. Supporting course work and cooperative research are offered in areas such as chemistry, biochemistry, genetics, microbiology, physics, engineering, statistics and economics.

Areas of study and research include food chemistry, food microbiology, food engineering, and food process and product development. These areas involve all foods, including dairy products, fruits, meats, poultry products, seafood, nutmeats and vegetables.

In order to pursue graduate study in the field of food science, the student must possess adequate information in the fundamentals of the area in which he expects to specialize. The student's undergraduate education should have prepared him in mathematics, chemistry, biological and physical sciences, as well as in the humanities and language skills.

The department participates in interdepartmental graduate student training programs. One is the training program in Industrial Waste Control and Abatement, administered by the Department of Civil Engineering. Students will pursue a course of study providing instruction in the essentials of waste control, with particular emphasis on processes used in food plant operations. Graduate training in water resources also is available wherein the student can pursue specialization

in industrial water use, water supply and pollution control. The School of Public Health in Chapel Hill offers courses that students can use for the minor field or for enriching their food science program by courses of study in environmental sciences. The Marine Sciences Program is an interdisciplinary area that offers the student research training in the technology of seafood processing and product development.

The Department of Food Science is housed in the Schaub Food Science Building which was completed in early 1968. This building provides integrated facilities for the entire program of the department. Included are research laboratories for chemistry, engineering and microbiology; teaching laboratories and lecture halls; and pilot equipment for the experimental processing of various foods.

FOR ADVANCED UNDERGRADUATES

FS 400 FOODS AND NUTRITION 3(3 0) S
Prerequisite: CH 220

A study of the health of an individual as related to food and the ability of his body to use food. Evaluation of normal diets and factors that promote optimal nutrition throughout life, and the application of biochemistry to utilization of foods.

FS 402 FOOD CHEMISTRY 3(3-0) F
Prerequisite: CH 220 or CH 221

An introduction to the biochemistry of foods with emphasis on the basic composition, structure, properties and nutritive values of food. The chemistry of changes occuring during processing and utilization of food will also be studied.

FS 404 (PO 404) POULTRY PRODUCTS 3(2-3) F
Prerequisites: CH 101, BS 100

Biological principles of processing, preservation and marketing of poultry meat and eggs.

FS 405 (MB 405) FOOD MICROBIOLOGY 3(2-3) F
Prerequisite: MB 301 or MB 401

The microorganisms of importance in foods, and their cultural and metabolic activities in foods. The physical and chemical destruction of microorganisms in foods and kinetics involved. The conversion of raw foods by microorganisms into altered foods and the nutrition, growth, and preservation of the cultures involved. Foods as vectors of human pathogens. The evolution of microbiological standards for foods.

FS 409 (ANS 409) MEAT AND MEAT PRODUCTS 3(2-3) S
Prerequisite: CH 220

A study of the basic principles involved in processing of beef, pork and lamb from the live animal to the various representative cured, fresh, canned and comminuted meat items currently produced.

FS 432 FOOD ENGINEERING II 3(2 3) S
Prerequisite: FS 331 (BAE 331)

The theory and principles of evaporation, drying and distillation will be discussed with emphasis on applications in the processing of foods. Instrumentation and control systems used in the food industry will also be presented.

FS 490 Food Science Seminar 1(1 0) S
Prerequisite: Senior standing

A review and discussion of scientific articles, new developments and topics of current interest in the food industry.

FS 503 Food Analysis 3(1 6) S
Prerequisites: CH 315, BCH 351, FS 402

A study of the principles, methods and techniques necessary for quantitative physical and chemical analyses of food and food products. Results of analysis will be studied and evaluated in terms of quality standards and governing regulations.
Mr. Cobb

FS 504 Advanced Food Chemistry 3(3 0) F
Prerequisite: BCH 551

Studies on the molecular properties of food components, their interaction and reactions and the physiochemical alterations occurring in the maturation, harvest, process and storage stages. Mr. Aurand

FS 506 (MB 506) Advanced Food Microbiology 3(1-6) S
Prerequisite: FS 405 (MB 405) or equivalent

The interactions of microorganisms in foods and their roles in food spoilage and bioprocessing. Cellular and molecular relationships in bacterial injury, repair and aging resulting from environmental stresses. Bacterial sporulation, germination and physiological properties of bacterial spores. Mr. Speck

FS 511 Food Research and Development 3(2-3) S
Prerequisites: FS 331 (BAE 331), FS 402, FS 405 (MB 405)

A study of the scientific principles underlying the development of new and improved food products and processes. Specific food industry problems will be studied by the case method. Special emphasis will be placed on the application of research and development principles to meat, poultry and fisheries industries.
Mr. Webb

FS 516 Quality Control of Food Products 3(2 3) S
Prerequisites: FS 331 (BAE 331), FS 402, FS 405 (MB 405)

A study of quality control fundamentals in the food industry including specifications and standards, testing procedures, sampling, statistical and quality control, and organization. Food products and industry problems will be used in the presentation with special emphasis on dairy products. Mr. Warren

FS 521 (HS 521) Food Preservation 3(2-3) F
Prerequisites: MB 401 or FS 405 (MB 405), FS 402, or BO 421

An examination of principles and methods employed in the preservation of foods. Major emphasis will be focused on thermal, freezing, drying and fermentation processes and their relationship to physical, chemical and organoleptic changes in product. In addition, the relationship of these preservation techniques to the development of an overall processing operation will be considered.
Messrs. Carroll, Hoover

FS 562 (HS 562) Post-Harvest Physiology 3(3 0) S
(See horticultural science, page 183.)

FS 591 Special Problems in Food Science Maximum 6 FS
Prerequisite: Graduate or senior standing

Analysis of scientific, engineering and economic problems of current interest in

foods. Credit for this course will involve the scientific appraisal and solution of a selected problem. The problems are designed to provide training and experience in research. Graduate Staff

FS 601 THEORY OF PHYSICAL MEASUREMENTS OF BIOPOLYMERS 3(2-3) S
Prerequisite: CH 525 or BCH 551

The theory and interpretation of various physical parameters of polymers will be discussed. The theoretical basis for the measurement of the parameter and consequently the limitations of the value obtained will be stressed. Particular emphasis will be given to the experimental design and interpretation of the data obtained which will yield the maximum amount of information. Mr. Swaisgood

FS 690 SEMINAR IN FOOD SCIENCE 1(1-0) FS

Preparation and presentation of scientific papers, progress reports and research and special topics of interest in foods. Graduate Staff

FS 691 SPECIAL RESEARCH PROBLEMS IN FOOD SCIENCE Credits Arranged

Directed research in a specialized phase of food science designed to provide experience in research methodology and philosophy. Graduate Staff

FS 699 RESEARCH IN FOOD SCIENCE Credits Arranged

Original research preparatory to the thesis for the Master of Science or Doctor of Philosophy degree. Graduate Staff

Forestry

GRADUATE FACULTY

Professor CHARLES B. DAVEY, *Head*

Professors: FRED S. BARKALOW, ARTHUR W. COOPER (on leave), ELLIS B. COWLING, JOHN W. DUFFIELD, MAURICE H. FARRIER, JAMES W. HARDIN, JOE O. LAMMI, T. EWALD MAKI, THOMAS O. PERRY, LEROY C. SAYLOR, RICHARD R. WILKINSON, BRUCE J. ZOBEL; *Professor USDA:* CHARLES S. HODGES; *Professor USFS:* GENE NAMKOONG; *Professors Emeritus:* WILLIAM D. MILLER, RICHARD J. PRESTON; *Adjunct Professors:* GEORGE H. HEPTING, LOUIS J. METZ; *Associate Professors:* LARRY F. GRAND, WILLIAM L. HAFLEY; *Associate Professor USFS:* BENEE F. SWINDEL; *Adjunct Associate Professors:* EDGAR W. CLARK, JEROME W. KOENIGS, ELMER G. KUHLMAN, CAROL G. WELLS; *Assistant Professor:* ROBERT C. KELLISON

The Department of Forestry offers graduate work leading to the degrees of Master of Forestry, Master of Science and Doctor of Philosophy.

The professional degree, Master of Forestry, is designed for students interested in the advanced applications of the fundamental principles of one of the specialized fields in forestry. The course program emphasizes professional specialization; a thesis is not required.

The Master of Science degree requires the student to become broadly educated in the scholarly disciplines in the field of forestry. Independent research and a thesis are required for this degree.

Students with a bachelor's degree in forestry may complete either of the master's programs in two academic years or less, provided they have met the undergraduate curriculum requirements in mathematics and the biological, physical

and social sciences. Candidates who do not hold an undergraduate degree in forestry may be required to start their programs with the summer camp.

The Doctor of Philosophy degree is available to students who can demonstrate high intellectual capacity and the ability to conduct original research and scholarly work at the highest levels.

Joint and associate faculty appointments with other departments provide exceptional opportunities for graduate studies in the forestry-related aspects of biometry, botany, ecology, economics, entomology, genetics, hydrology, plant pathology, soil science and wildlife science. Students who are concerned with the problems of restoring and improving the quality of our environment may find meaningful graduate study in the Department of Forestry.

The department is now housed in the new and modern facilities of Biltmore Hall. The completion of this building in 1970 enabled the entire School of Forest Resources to be housed in three adjacent buildings on the southwest side of campus. Facilities for forest biological research include a phytotron, two greenhouses, a small experimental nursery and an off-campus laboratory equipped for the study of carbon and water metabolism of tree seedlings. The experimental and production forests of the school total more than 50,000 acres. The Hofmann Forest on the coastal plain, the Goodwin Forest at the edge of the sandhills, and the Schenck, Hope Valley and Hill forests in the Piedmont provide a variety of forest types and problems in the management of timber, water, wildlife and recreational resources. The Hill and Schenck forests include natural areas, excluded from normal management operations, for the study of forest ecology.

The department has exceptionally close working relations, including three large cooperative programs of research and development, with public agencies and the forest industries of the southeastern United States.

FOR ADVANCED UNDERGRADUATES

FOR 405 FOREST LAND MANAGEMENT 5(2 6 2) F
Prerequisites: FOR 272, FOR 452

Management of forest lands for multiple benefits. The principles and techniques applied in regulating regeneration, species composition, growth and quality of woody vegetation; the use of planting, seeding, cutting, herbicides and fire in the management of vegetation. The application of financial principles in making decisions regarding investments in forest management.

Messrs. Bryant, Duffield

FOR 406 FOREST LAND INVENTORY AND PLANNING 6(2 12) S
Prerequisite: FOR 405

Applications of land management systems, including silviculture, protection, utilization and related problems in evaluation of assigned forest areas. Students complete a resource inventory and submit individual plans for management of the assigned tract. Mr. Bryant

FOR 423 (WPS 423) LOGGING AND MILLING 3(2-3) F

(See wood and paper science, page 329.)

FOR 435 (WPS 435) SYSTEMS ANALYSIS IN FOREST PRODUCTS 3(3 0) S

(See wood and paper science, page 329.)

FOR 452 SILVICS 4(3-2) S
Prerequisites: BO 200, CH 103, PY 221 or PY 212, mathematics through calculus

Physiological ecology of the plants composing forest communities, including consideration of genotypic and phenotypic variation. Plant responses to environmental factors, including plant interactions are emphasized as a basis for developing techniques of manipulating forest communities. Consideration is given to effects of ecosystem manipulation on aesthetic values and on wildlife habitats. Mr. Perry

FOR 462 ARTIFICIAL FORESTATION 2(1-3) S

Biology of seed production for forest trees; forest tree seed collection, extraction, storage and testing; biology of tree seedling growth, soil aspects of nursery management; forest nursery operation; soil aspects of site preparation, planting and direct seeding; reforestation operations. (Offered spring 1972 and alternate years). Messrs. Davey, Duffield

FOR 472 RENEWABLE RESOURCE MANAGEMENT 3(3-0) S
Prerequisites: A basic course in biology and economics; junior or senior standing

The concepts and problems of coordinated use and management of the renewable resources, namely soil, water, vegetation and fauna. Man as a biological factor interacting with other components of terrestrial ecological systems, particularly forests and related communities. Consideration is given to the interrelationships of forests, water, range-land, wildlife and outdoor recreation and their aesthetic and economic values. Inventory and management techniques and economic policies relating to renewable resources are examined and discussed. (Not open to forestry majors.) Mr. Preston

FOR 491 (WPS 491) SENIOR PROBLEMS IN FOREST RESOURCES Credits Arranged
Prerequisite: Consent of department

Problems selected with faculty approval in the areas of management or technology. Staff

FOR 492 (WPS 492) SENIOR PROBLEMS IN FOREST RESOURCES Credits Arranged
Prerequisite: Consent of department

Problems selected with faculty approval in the areas of management or technology. Staff

FOR GRADUATES AND ADVANCED UNDERGRADUATES

FOR 501 FOREST INFLUENCES AND WATERSHED MANAGEMENT 3(3-0) F
Prerequisite: Advanced undergraduate or graduate standing

Study of the effects of woody vegetation on climate, water and soil, with applications of the knowledge of forest influences to management of forest land resources, including conservation and yield of water, stabilization of streamflow and soils, reduction of sedimentation and general improvement of the environment. Mr. Maki

FOR 512 FOREST ECONOMICS 3(3-0) S
Prerequisite: Basic course in economics or consent of instructor

Economics and social value of forests; supply of, and demands for forest products; land use; forestry as a private and a public enterprise; economics of the forest industries. Mr. Holley

FOR 553 FOREST PHOTOGRAMMETRY 3(2-3) S
Prerequisite: Basic measurements course or consent of instructor

The stereoscopic use of aerial photographs for land use and vegetation interpretation will be emphasized. Some developments in remote sensing of environment will be reviewed, including infrared light, thermal infrared, microwave and radar imagery. Laboratory exercises include identification of plant cover and culture, measurement of elevations and heights of objects, determination of tree cover densities and volumes, road location and rudimentary mapping. Mr. Lammi

FOR 571 ADVANCED FOREST MENSURATION 3(2 2) S
Prerequisites: FOR 272, ST 311

Study of the development of mathematical models to describe forest resources phenomena; criteria for evaluating the "goodness" of such models; and methods of data collection for use in the evaluation. Mr. Hafley

FOR 572 CONSERVATION POLICY ISSUES 3(3-0) S
Prerequisite: Seniors and graduates, or consent of instructor

Analysis of the attitudes of selected private groups and public agencies toward multiple resource development. Special attention is directed to the trends in development of forest resource policies, timber management objectives, private industry activity in forestry development, recreation and multiple use, education, research, watersheds, governmental activity, interaction in international forestry affairs and the role of professional foresters and related specialists in multiple use resource management. Mr. Lammi

FOR 591 (WPS 591) FORESTRY PROBLEMS Credits Arranged
Prerequisite: Senior or graduate standing

Assigned or selected problems in the field of silviculture, harvesting operations, lumber manufacturing, wood science, pulp and paper science, wood chemistry or forest management. Staff

FOR 599 (WPS 599) METHODS OF RESEARCH IN FORESTRY Credits Arranged
Prerequisite: Senior or graduate standing

Research procedures, problem analysis, working plan preparation, interpretation and presentation of results; evaluation of selected studies by forest research organi zations; techniques and constraints in the use of sample plots. Staff

FOR GRADUATES ONLY

FOR 611 (GN 611) FOREST GENETICS 3(3 0) S
Prerequisites: GN 411, consent of instructor

Application of genetic principles to silviculture, management and pulp utilization. Emphasis is on variations in wild populations, on the bases for selection and desirable qualities and on fundamentals of controlled breeding. Messrs. Saylor, Zobel

FOR 612 (GN 612) ADVANCED TOPICS IN QUANTITATIVE GENETICS 3(3-0) F
Prerequisites: GN 611 (FOR 611), GN 626 (ST 626) or GN 603 (ANS 603)
or consent of instructor

Advanced topics in statistics and population genetics pertinent to current research problems in genetics with special applications to forestry. Basic statistical and genetic theory is to be reviewed as bases for intensive study of selection theory and experimental and mating design evaluation. The genetics of natural populations are also to be studied for evolutionary interest as well as for their implications to breed-

ing theory. The format shall be part lecture and part student and faculty discussion of current research. Mr. Namkoong

FOR 613 SPECIAL TOPICS IN SILVICULTURE 3(2-1) F
Prerequisite: Consent of instructor

Critical examination of selected topics, with special emphasis on concepts and phenomena which distinguish forests from other biotic communities and silviculture from other fields of applied biology. Mr. Duffield

FOR 614 ADVANCED TOPICS IN FOREST LAND MANAGEMENT 3(3-0) F
Prerequisite: FOR 405 or equivalent

A collation of the disciplines in silvics, forest growth estimation, growing stock regulation, forest soil management and site quality evaluation, forest influences, and silviculture, with emphasis on the interrelationships of these disciplines in the management of forest land resources and the applications to forest management systems. Mr. Maki

FOR 691 (WPS 691) GRADUATE SEMINAR 1(1-0) FS
Prerequisite: Graduate standing in forestry or closely allied fields

Presentation and discussion of progress reports on research, special problems and outstanding publications in forestry and related fields. Graduate Staff

FOR 692 ADVANCED FOREST MANAGEMENT PROBLEMS Credits Arranged
Prerequisite: Graduate standing

Directed studies in forest management. Graduate Staff

FOR 699 (WPS 699) PROBLEMS IN RESEARCH Credits Arranged
Prerequisite: Graduate standing

Specific forestry problems that will furnish material for a thesis. Graduate Staff

Genetics

GRADUATE FACULTY

Professor THURSTON J. MANN, *Head*

Professors: CAREY H. BOSTIAN, DANIEL S. GROSCH, WARREN D. HANSON, DALE F. MATZINGER, LAWRENCE E. METTLER, ROBERT H. MOLL, TERUMI MUKAI, LEROY C. SAYLOR, BENJAMIN W. SMITH, STANLEY G. STEPHENS, ANASTASIOS C. TRIANTAPHYLLOU; *Professor USFS:* GENE NAMKOONG; *Associate Professors:* WESLEY E. KLOOS, CHARLES S. LEVINGS, III, HENRY E. SCHAFFER; *Associate Professors USDA:* LAWRENCE G. BURK, CHARLES W. STUBER; *Assistant Professors:* FRANKLIN M. JOHNSON

ASSOCIATE MEMBERS OF THE DEPARTMENT

Professors: JAY L. APPLE, FRANK B. ARMSTRONG, FRED D. COCHRAN, COLUMBUS C. COCKERHAM, WILL A. COPE, JOHN W. DUFFIELD, DONALD A. EMERY, GENE J. GALLETTA, DAN U. GERSTEL, EDWARD W. GLAZENER, WALTON C. GREGORY, PAUL H. HARVEY, FRANK L. HAYNES, JR., TEDDY T. HEBERT JAMES E. LEGATES, PHILLIP A. MILLER, THOMAS O. PERRY, LYLE L. PHILLIPS, NATHANIEL T. POWELL , JOHN O. RAWLINGS, DONALD L. THOMPSON, DAVID H.

TIMOTHY, BRUCE J. ZOBEL; *Professors USDA:* CHARLES A. BRIM, JAMES F. CHAPLIN, JOSHUA A. LEE; *Associate Professors:* WILLIAM L. BLOW, EMMETT U. DILLARD, EUGENE J. EISEN, MAJOR M. GOODMAN, CHARLES F. MURPHY, ODIS W. ROBISON, EARL A. WERNSMAN; *Associate Professor USDA:* GEORGE R. GWYNN; *Assistant Professor USDA:* CECIL TESTER

Graduate study under the direction of the genetics faculty may enable the student to qualify for the Master of Science or the Doctor of Philosophy degrees. A candidate for the master's degree must acquire a thorough understanding of genetics and its relation to other biological disciplines and must present a thesis based upon his own research. In addition to a comprehensive knowledge of his field, a candidate for the doctorate must demonstrate his capacity for independent investigation and scholarship in genetics.

At North Carolina State University there are no sharp divisions along departmental lines or between theoretical and applied aspects of genetics research. The members and associate members of the genetics faculty are located in six different departments of the School of Agriculture and Life Sciences, the School of Forest Resources and the School of Physical and Mathematical Sciences. They are studying an extremely wide range of genetic problems and are utilizing not only the "classic" laboratory material (arabidopsis, rumex, bacteria, *Drosophila*, *Habrobracon* and mice) but also farm animals and agricultural and forest plants of the region. A student has, therefore, a wide choice of research problems in any of the following fields: cytology and cytogenetics, microbial and biochemical genetics, physiological and developmental genetics, evolution and speciation, quantitative and population genetics, and the application of genetics to breeding methodology.

The offices and laboratories of the department are located in Gardner Hall with greenhouse facilities adjacent to the building. A genetics garden for use in the intensive research with plants and teaching functions is located three miles from the departmental offices. The departmental staff and the associate faculty members in animal science, biochemistry, crop science, horticultural science, poultry science, plant pathology, statistics and the School of Forest Resources are most fortunate in being able to draw upon the extensive facilities of the North Carolina Agricultural Experiment Station.

FOR ADVANCED UNDERGRADUATES

GN 411 THE PRINCIPLES OF GENETICS 3(3-0) FS
Prerequisite: BS 100

An introductory course. The physical and chemical basis of inheritance; genes as functional and structural units of heredity and development; qualitative and quantitative aspects of genetic variation. Mr. Johnson

GN 412 ELEMENTARY GENETICS LABORATORY 1(0 2) FS
Prerequisite or corequisite: GN 411

Experiments and demonstrations to provide an opportunity to gain practical experience in crossing and classifying a variety of genetic materials including two generations of *Drosophila*. Mr. Johnson, Graduate Staff

FOR GRADUATES AND ADVANCED UNDERGRADUATES

GN 504 HUMAN GENETICS 3(3-0) S
Prerequisite: GN 301 or GN 411, or equivalent

Basic principles and methods of research in human genetics will be presented. Current knowledge and important areas of research will be studied. This course is intended to serve the needs of advanced undergraduates and graduates in the social and biological sciences. Messrs. Bostian, Schaffer

GN 505 GENETICS I 4(3-2) F
Prerequisite: GN 411 or equivalent

Part I of a course sequence designed to serve as a foundation for graduate programs in genetics. As such, a balanced and comprehensive survey of each of the major fields of genetics must be presented in integrated form. Concepts based upon family analysis and a study of individual organisms will be presented here. Coverage will include general plant and animal genetics, biochemical and microbial genetics, and physiological and developmental genetics. Messrs. Grosch, Kloos

GN 506 GENETICS II 4(3-2) S
Prerequisite: GN 505 or consent of instructor

This course represents the second portion of a two semester sequence in general genetics, which is presented at the intermediate level and directed primarily to beginning graduate students. Emphasis is placed on the basic principles and modern concepts of cytogenetics, population genetics and quantitative genetics. These subjects each represent about one-third of the course and are integrated with those of the first semester course as much as possible, with the primary synthesis being directed toward the dynamic aspects of evolutionary theory, including both intra and interpopulational phenomena. Mr. Mettler, Graduate Staff

GN 508 (ANS 508) GENETICS OF ANIMAL IMPROVEMENT 3(3-0) S

(See animal science, page 67.)

GN 513 CYTOGENETICS 4(3-2) F
Prerequisite: GN 506 or consent of instructor

Classical and contemporary problems of chromosome structure, behavior and transmission. Euchromatin and heterochromatin. Recombination. Structural and numerical aberrations of chromosomes and the effects upon breeding systems of plants and animals. Interspecific hybridization. Polyploidy. Lectures and laboratory. Messrs. Galletta, Gerstel

GN 520 (PO 520) POULTRY BREEDING 3(2-2) F

(See poultry science, page 271.)

GN 532 (ZO 532) BIOLOGICAL EFFECTS OF RADIATIONS 3(3-0) S
Prerequisite: BS 100 or GN 301 or consent of instructor

Qualitative and quantitative effects of radiations (other than the visible spectrum) on biological systems, to include both morphological and physiological aspects in a consideration of genetics, cytology, histology and morphogenesis. Mr. Grosch

GN 540 (ZO 540) EVOLUTION 3(3-0) F
Prerequisite: GN 411; undergraduates need consent of instructor

The facts and theories of evolution in plants and animals. The causes and consequences of organic diversity. Mr. Smith

GN 541 (CS 541, HS 541) PLANT BREEDING METHODS 3(3-0) F

(See crop science, page 112.)

GN 542 (CS 542, HS 542) PLANT BREEDING FIELD PROCEDURES 2(0-4) Sum.

(See crop science, page 113.)

GN 545 (CS 545) ORIGIN AND EVOLUTION OF CULTIVATED PLANTS 2(2-0) S

(See crop science, page 113.)

GN 550 (ZO 550) EXPERIMENTAL EVOLUTION 3(3-0) F
Prerequisite: GN 506 or consent of instructor

Experimental evolution deals primarily with microevolutionary processes examined at the inter- and intra specific population level. A review of the results from experimental population studies and analyses of natural populations concerning variation patterns and adaptation, natural selection, polymorphism, introgression, population breeding structure, isolating mechanism, etc., is made and interpreted in relation to Neo-Darwinian concepts of the origin of species. (Offered 1973-74 and alternate years.) Mr. Mettler

GN 561 (BCH 561, MB 561) BIOCHEMICAL AND MICROBIAL GENETICS 3(3-0) F
Prerequisites: BCH 351 or BCH 551, GN 411 or GN 505, MB 401 or equivalent

The course will include the development of the fields of biochemical and microbial genetics and will emphasize both the techniques and concepts utilized in current research. Mr. Armstrong

FOR GRADUATES ONLY

GN 603 (ANS 603) POPULATION GENETICS IN ANIMAL IMPROVEMENT 3(3-0) F

(See animal science, page 68.)

GN 611 (FOR 611) FOREST GENETICS 3(3-0) S

(See forestry, page 163.)

GN 612 (FOR 612) ADVANCED TOPICS IN QUANTITATIVE GENETICS 3(3-0) F

(See forestry, page 163.)

GN 613 (CS 613) PLANT BREEDING THEORY 3(3-0) S

(See crop science, page 113.)

GN 626 (ST 626) STATISTICAL CONCEPTS IN GENETICS 3(3-0) S

(See statistics, page 303.)

GN 631 MATHEMATICAL GENETICS 3(3-0) F
Prerequisites: GN 506, ST 511, or consent of instructor

Mathematical models of genetic systems, including probabilistic and deterministic formulations. Theory of survival of mutations, genetic linkage and dynamics of populations. (Offered 1972-73 and alternate years.) Mr. Schaffer

GN 633 PHYSIOLOGICAL GENETICS 3(3-0) S
Prerequisites: GN 505 or equivalent

Recent advances in physiological genetics. Attention will be directed to literature

on the nature and action of genes, and to the interaction of heredity and environment in the expression of the characteristics of higher organisms. Mr. Grosch

GN 641 COLLOQUIUM IN GENETICS 2(2-0) FS
Prerequisites: Graduate standing, consent of instructor

Informal group discussion of prepared topics assigned by the instructor.
Graduate Staff

GN 691 SEMINAR 1(1-0) FS
Prerequisite: Graduate standing

GN 695 SPECIAL PROBLEMS IN GENETICS 1-3 FS
Prerequisites: Advanced graduate standing, consent of instructor

Special topics designed for additional experience and research training.
Graduate Staff

GN 699 RESEARCH Credits Arranged
Prerequisites: Graduate standing, permission of adviser

Original research related to the student's thesis problem. A maximum of six credits for the master's degree; by arrangement for the doctorate. Graduate Staff

Geology

(For a listing of graduate faculty and departmental information see geosciences, page 171.)

FOR ADVANCED UNDERGRADUATES

GY 415 MINERAL EXPLORATION AND EVALUATION 3(2-3) S
Prerequisites: GY 440, GY 452

Application of the principles of geology, geophysics and geochemistry to the discovery and evaluation of mineral deposits. Design of mineral exploration and development programs based on knowledge of the unique thermodynamic, geochemical and tectonic features that control mineral formation and concentrations in well-known mining districts, especially those yielding ferrous, base and precious metals. Review of economic and technological factors governing the value of mineral deposits. Field trips.

GY 440 IGNEOUS AND METAMORPHIC PETROLOGY 4(3-3) S
Prerequisites: GY 120 or GY 220, GY 331

Minerals, rocks and mineral deposits that are formed at high temperatures and pressures by crystallization or solidification of molten magma or by solid state recrystallization of older rocks. Application of principles of thermodynamics and of phase-rule chemistry, and of the results of modern high pressure-temperature laboratory research on the stability fields of crystalline phases, to an understanding of igneous and metamorphic rocks. Identification, classification, occurrence, origin and economic value of the principal igneous and metamorphic rocks.

GY 452 EXOGENIC MATERIALS AND PROCESSES 4(3-3) S
Prerequisites: GY 120 or GY 220, GY 331

Identification, classification, geologic occurrence, origin and economic value of minerals, rocks and mineral deposits formed by physical, chemical and biological

processes at low temperatures and pressures at and near the earth's surface. Hydrodynamics of sediment transport and deposition, settling velocities and size sorting, chemical and biochemical precipitation from aqueous solutions. Principles of division of stratified terraines into natural units, correlation of strata, identification of depositional environments and facies analysis.

GY 461 ENGINEERING GEOLOGY 3(3-0) F
Prerequisite: GY 120 or GY 220

The application of geologic principles to engineering practice; analysis of geologic factors and processes affecting specific engineering projects. (Offered 1973 74 and alternate years.)

GY 462 GEOLOGICAL SURVEYING 3(1 5) S
Prerequisite: GY 120

Methods of field observation and use of geologic surveying instruments in surface and underground work; representation of geologic features by maps, sections and diagrams. Lectures, laboratories and field work.

GY 465 GEOLOGICAL FIELD PROCEDURES 6 Sum.
Prerequisite: GY 351 or special consent

A six-week summer field course. Practical field procedures and instruments commonly used to procure geologic data for evaluating mineral deposits, solving engineering problems involving earth materials and drawing scientific conclusions. Observation of geologic phenomena in their natural setting. Large and intermediate scale geologic mapping of surface features and large scale mapping underground in mine workings.

GY 486 WEATHER AND CLIMATE 2(2-0) F
Prerequisites: MA 102 or MA 112, PY 211 212 or PY 221

A discussion of basic principles of meteorology and climatology. Topics discussed include the atmosphere, radiation, moisture, pressure and wind, atmospheric equilibrium, air masses and fronts. Macro- and microclimate and the climate of North Carolina are also covered.

GY 491, 492 SEMINAR ON SELECTED GEOLOGIC TOPICS 1 3 FS

Reports and discussion of geological topics of current interest with attention to methodology, bibliography and research techniques.

FOR GRADUATES AND ADVANCED UNDERGRADUATES

GY 522 PETROLEUM GEOLOGY 3(3 0) S
Prerequisite: GY 452

Properties, origin and modes of occurrence of petroleum and natural gas. Geologic and economic features of the principal oil and gas fields, mainly in the United States. (Offered 1973-74 and alternate years.) Mr. Leith

GY 532 ORE MICROSCOPY 3(0 6) F
Prerequisite: GY 331

The theory and technique of microscopic investigation of opaque ore minerals, ores and mill products produced by beneficiation of ores. Studies of compositions and textures of materials in polished surfaces are based on observations of optical and physical properties, etch reactions and microchemical tests. (Offered 1973-74 and alternate years.) Mr. Brown

GY 542 MICROSCOPIC PETROGRAPHY 3(1-4) S
Prerequisite: GY 440

Systematic study by microscopic techniques of the constitution and origin of consolidated rocks. Graduate Staff

GY 545 ADVANCED PETROLOGY 3(3-0) F
Prerequisite: GY 440

Study of physiochemical principles related to igneous and metamorphic petrogenesis; consideration of general principles and specific problems such as differentiation, origin of magmas and metamorphism. (Offered 1973-74 and alternate years.) Mr. Spence

GY 552 EXPLORATORY GEOPHYSICS 3(3-0) S
Prerequisites: GY 351, PY 208 or PY 212

Fundamental principles underlying all geophysical methods; procedure and instruments involved in gravitational, magnetic, seismic, electrical and other methods of studying geological structures and conditions. Spontaneous potential, resistivity, radioactivity, temperature and other geophysical logging methods. Study of applications and interpretations of results. (Offered 1972-73 and alternate years.) Mr. Leith

GY 563 APPLIED SEDIMENTOLOGY 3(2-3) F
Prerequisites: GY 452, ST 361

Extension of GY 452, with emphasis on coarser grained detrital and chemical sedimentary rocks. Sampling of sedimentary population, critical study of assumptions underlying standard measurement techniques; treatment, testing and evaluation of sedimentary data; application to problems in sedimentology. Mr. Cavaroc

GY 564 LITHOSTRATIGRAPHY AND BASIN ANALYSIS 3(2 3) S
Prerequisite: GY 452 or graduate standing

Fabric of large sedimentary basins in terms of the spatial distribution of component major rock facies; current litho-genetic models illustrating internal lithic relationships, variability and predictability; evolution of litho-genetic units; comparison with recent equivalents; field trips. Mr. Cavaroc

GY 565 HYDROGEOLOGY 3(3-0) S
Prerequisite: GY 452

Occurrence and sources of surface and subsurface water. Relationships of surface water to subsurface water. Rock properties affecting infiltration, movement, lateral and vertical distribution, and quality of ground water. Determination of permeability, capacity, specific yield and other hydraulic characteristics of aquifers. Principles of well design, legal aspects of water supplies. (Offered 1972-73 and alternate years.) Mr. Welby

GY 567 GEOCHEMISTRY 3(3-0) F
Prerequisite: CH 331 or CH 433

The quantitative distribution of elements in the earth's crust, the hydrosphere and the atmosphere. Application of the laws of chemical equilibrium and resultant chemical reactions to natural earth systems. Geochemical application of Eh-pH diagrams. Geochemical cycles. Isotope geochemistry. (Offered 1972-73 and alternate years.) Mr. Brown

GY 581 GEOMORPHOLOGY 3(2 3) F
Prerequisites: GY 120 plus appropriate background

A systematic study of land forms and their relations to processes, stages of development and adjustment to underlying structure. Lectures, map interpretations and field trips. Mr. Carson

GY 582 QUATERNARY GEOLOGY 3(3-0) S
Prerequisites: GY 120, senior standing

Glaciology, glacial geology, Pleistocene stratigraphy, periglacial geomorphology; Quaternary volcanism, tectonism, and sea level fluctuations; late Cenozoic climate changes; field trips. (Offered spring 1972 and alternate years.) Mr. Carson

GY 584 (MAS 584) MARINE GEOLOGY 3(3 0) S
Prerequisites: GY 452 or GY 120 plus appropriate background

Morphology, structure and origin of ocean basins with their diverse features and their relations to the continents. Physical and chemical properties of the oceans, sedimentation in the marine environment and near shore features. The economic potential of mineral resources derived from oceanic areas. (Offered 1973 74 and alternate years.) Mr. Welby

GY 593 ADVANCED TOPICS IN GEOLOGY 1 6 FS
Prerequisite: Consent of staff

Special study of some advanced phases of geology. Graduate Staff

FOR GRADUATES ONLY

GY 611, 612 ADVANCED ECONOMIC GEOLOGY 3(3-0) FS
Prerequisites: GY 440, GY 452

Detailed study of the origin and occurrence of specific mineral deposits. Mr. Brown

GY 695 SEMINAR 1(1-0) FS
Prerequisite: Graduate standing

Scientific articles, progress reports and special problems of interest to geologists and geological and mining engineers discussed. Graduate Staff

GY 699 GEOLOGICAL RESEARCH Credits Arranged
Prerequisite: Consent of instructor

Lectures, reading assignments and reports; special work in geology to meet the needs and interests of the students. Thesis problem. Graduate Staff

Geosciences

GRADUATE FACULTY

Professor CARLTON J. LEITH, *Head*
Professors: HENRY S. BROWN, EARL G. DROESSLER, JOHN LYMAN, JOHN M. PARKER, III, WALTER J. SAUCIER; *Associate Professor:* CHARLES W. WELBY; *Adjunct Associate Professor:* JAMES R. SMITH; *Assistant Professors:* ROBERT J. CARSON,

III, Victor V. Cavaroc, Jr., Norden E. Huang, Charles E. Knowles, William H. Spence, Allen H. Weber; *Adjunct Assistant Professors:* Walter D. Bach, James T. Peterson

The Department of Geosciences offers graduate programs leading to the Master of Science degree in geology and, as its input into an inter institutional graduate program in Marine Sciences in the University of North Carolina, the department also offers courses for graduate and advanced undergraduate students in meteorology and physical oceanography. The Master of Science and Doctor of Philosophy degrees in geological, meteorological, and physical oceanography are granted through the University Marine Sciences Program page 199).

Candidates for admission to the graduate program in geology should hold a bachelor's degree in geology or a satisfactory equivalent, preferably with a strong background in physics, chemistry and mathematics. For graduate study in meteorological oceanography the required background includes chemistry, physics, mathematics through introductory differential equations, and a basic knowledge of atmospheric physics, the mechanics of the atmosphere, and the analysis and laboratory treatment of atmospheric distributions, processes and developments. The candidate for a graduate program in physical oceanography should hold a bachelor's degree in one of the physical sciences or engineering with a strong background in physics and mathematics. In each of the three disciplines the graduate program for the master's degree consists of a minimum of 30 semester hours credit divided between major and minor fields, and a research thesis is required. The student concentrating in geological, meteorological, or physical oceanography at the doctorate level will include in his program of study the appropriate graduate courses in geology, meteorology and/or physical oceanography. The general requirements for a Ph.D. program in marine sciences are described on page 200.

A great variety of interesting research problems involving both field and laboratory aspects is to be found within a short distance of Raleigh. Facilities are available for research in mineralogy, petrology, hydrogeology, economic geology, engineering geology, meteorology, physical oceanography and geophysical fluid dynamics. Excellent collections of geoscience literature are available in the University library and elsewhere in the Research Triangle area. Consultations with scientists of the federal and state agencies in Raleigh as well as with the staffs of the neighboring universities are encouraged.

Financial aid is available through laboratory teaching assistantships and assistantships on faculty research projects. Government agencies and industrial concerns provide part-time employment from time to time. Small grants from the state sometimes are available to help with thesis expenses.

The graduate programs are directed to the advanced training of qualified students interested in the scientific aspects and practical applications of the geosciences. Many professional problems in the geosciences today require more specialized and detailed training in theory and methods than can be included in an undergraduate curriculum. Occupational opportunities in geology include the location and evaluation of mineral deposits, the provision of satisfactory water supplies, the disposal of fluid and solid wastes, and the assessment of geologic conditions affecting conservation and civil engineering projects. Geology students with advanced training find employment in the petroleum, mining and construction industries, with various state and federal government agencies, and in education and research institutions. Physical oceanographers can find employment in academic, business and government agencies with interests that include coastal, estuarine or deep water oceanography. The research areas in physical oceanog-

raphy may be directed toward field, experimental or theoretical problems. Similar employment opportunities exist for meteorological oceanographers, concerned primarily with the various interactions of the oceans and the atmosphere.

Guidance and Personnel Services

GRADUATE FACULTY

Professor WILLIAM E. HOPKE, *Head*
Professors: ROY N. ANDERSON, CHARLES G. MOREHEAD; *Assistant Professor:* LAWRENCE K. JONES

The department offers work leading to the Master of Science, Master of Education and Doctor of Education degrees with a major in the field of guidance and personnel services (or counselor education . Each of these degrees is designed to prepare individuals for guidance and personnel positions at various levels in elementary and secondary schools, junior and community colleges, trade and technical schools and institutes, institutions of higher education, agencies such as employment and rehabilitation offices), as well as guidance and personnel work in business, industry and government. The student may specialize in one of several areas depending upon his career goals.

It is desirable for an applicant to have had undergraduate or graduate course work in economics, education, psychology, sociology or social work. Students accepted into the department are those who anticipate devoting full or part time to guidance and personnel work. Teachers, administrators and others who wish to increase their knowledge of guidance and personnel work may enroll for courses as a graduate minor or for certification renewal.

Admission requirements for the department are: a minimum of a B average in the undergraduate major; satisfactory scores on the Aptitude section of the Graduate Record Examination; three satisfactory letters of recommendation in regard to previous educational and employment experiences, personal characteristics and emotional maturity. In some cases, provisional acceptance is granted where some of the requirements are not met.

The master's and doctoral programs include a core of guidance and personnel courses to be selected according to the student's vocational goals. Students may select their minor from the following areas: economics, education, psychology, sociology and statistics. A master's student may select a program which meets the requirements for the Counselor's Certificate issued by the North Carolina State Department of Public Instruction as well as counselor certification in many other states.

The department also provides service courses in guidance and personnel for undergraduate students in the School of Education.

A limited number of graduate assistantships are available annually in several departments of the School of Education and through the Division of Student Affairs.

FOR GRADUATES AND ADVANCED UNDERGRADUATES

ED 520 PERSONNEL AND GUIDANCE SERVICES 3(3-0) FS Sum.
Prerequisite: Six hours of education or psychology

An introduction to the philosophies, theories, principles and practices of personnel

and guidance services; the relationship of personnel services with the purposes and objectives of the school and the curriculum. Graduate Staff

ED 521 INTERNSHIP IN GUIDANCE AND PERSONNEL SERVICES Credits Arranged FS
Prerequisite: Eighteen hours in department

A continuous full time internship of at least one half semester. Framework of school and community. Work with students, teachers, administrators, guidance and pupil personnel workers, parents and resource personnel in community. Supervision of intern by guidance personnel in a school as well as by course instructors.
Graduate Staff

ED 524 OCCUPATIONAL INFORMATION 3(3-0) FS Sum.
Prerequisites: Six hours of education or psychology, ED 520 or equivalent

This course is intended to give teachers, counselors, placement workers and personnel workers in business and industry an understanding of how to collect, classify, evaluate and use occupational and educational information. This will include a study of the world of work, sources of occupational information, establishing an educational-occupational information library, using educational, occupational and social information, and sociological and psychological factors influencing career planning. Mr. Hopke

ED 530 GROUP GUIDANCE 3(3-0) FS Sum.
Prerequisites: Six hours of education or psychology, ED 520 or equivalent

This course is designed to help teachers, counselors, administrators and others who work with groups, or who are responsible for group counseling and guidance activities, to understand the theory and principles of effective group work, to develop skill in using specific counseling and guidance techniques, and to plan and organize group activities in the secondary school and other institutions.
Mr. Morehead

ED 533 ORGANIZATION AND ADMINISTRATION OF GUIDANCE SERVICES 3(3 0) S Sum.
Prerequisites: Graduate standing, ED 520 or equivalent

This course is designed for school counselors, prospective counselors, personnel and guidance directors, and school administrators. The philosophy and scope of guidance and personnel services; the functions and responsibilities of personnel involved; basic principles and current practices in planning, developing, operating and supervising guidance and personnel services will be studied. Administrative relationships, utilization of school staff, interrelationships of guidance and personnel services with instruction and evaluation of guidance and personnel services will be considered. Graduate Staff

ED 534 GUIDANCE IN THE ELEMENTARY SCHOOL 3(3 0) S Sum.
Prerequisite: Nine hours of psychology or consent of instructor

Designed for acquainting elementary school teachers, counselors and administrators with theory, practice and organization of elementary school guidance.
Graduate Staff

ED 535 STUDENT PERSONNEL WORK IN HIGHER EDUCATION 3(3-0) F Sum.
Prerequisite: Nine hours of psychology or consent of instructor

Examines practices in various areas of student personnel work. Studies both structure and function of personnel programs in higher education. Graduate Staff

ED 540 INDIVIDUAL AND GROUP APPRAISAL I 3(3-0) F
Prerequisites: ED 520, PSY 535, or equivalent

Use of group tests of intelligence, interest and achievement in educational and career planning and in placement. Theories of intelligence and interest will be

followed by laboratory in evaluating, administering and interpreting widely used group tests of intelligence, interest and achievement. Emphasis is on the use of group tests in group guidance. Mr. Morehead

ED 590 INDIVIDUAL PROBLEMS IN GUIDANCE Maximum 6 FS
Prerequisite: Six hours graduate work in department or equivalent

Intended for individual or group studies of one or more of the major problems in guidance and personnel work. Problems will be selected to meet the interests of individuals. The workshop procedure will be used whereby special projects, reports and research will be developed by individuals and by groups. Graduate Staff

FOR GRADUATES ONLY

ED 631 VOCATIONAL DEVELOPMENT THEORY 3(3-0) F
Prerequisite: Six hours from following fields education or psychology

A study of the major theories of vocational development with implications for counseling and career planning in various operational situations. An interdisciplinary approach will be discussed: economics, education, psychology and sociology. The research and the applications of research will be discussed. Graduate Staff

ED 633 TECHNIQUES OF COUNSELING 3(3-0) FS Sum.
Prerequisite: Nine hours from following fields—economics, education, psychology or sociology

This course is designed to aid the personnel worker in the secondary school, college, employment office or social agency to develop an understanding and to develop skill in counseling techniques; philosophies, theories, principles and practices of counseling will be considered. Students will become acquainted with counseling techniques through lectures, demonstrations, case histories and tape recordings. Attention will be given to both diagnosis and treatment. Mr. Hopke

ED 636 OBSERVATION AND SUPERVISED FIELD WORK Maximum 3 FS
Prerequisite: Consent of instructor

Provides opportunity for observation and practice of guidance and personnel services in schools, institutions of higher education, agencies, business and industry. Graduate Staff

ED 640 INDIVIDUAL AND GROUP APPRAISAL II 3(3-0) S
Prerequisites: ED 520, ED 540, PSY 535, or equivalent

Use of individual tests in the individual counseling of normal students. Theories of aptitudes and personality will be followed by laboratory in evaluating, adminis tering and interpreting individual tests of intelligence, special aptitudes and personality. Mr. Morehead

ED 641 LABORATORY AND PRACTICUM EXPERIENCES IN COUNSELING 2-6 FS Sum.
Prerequisites: Advanced graduate standing, consent of instructor

A practicum course in which the student participates in actual counseling experience under supervision in a school, college, social service agency, employment office and business or industrial establishment. The student may observe and participate in some personnel and guidance services and may study the organization and administration of the program. Graduate Staff

ED 666 SUPERVISION OF COUNSELING 3(1-8) FS Sum.
Prerequisite: Consent of instructor

A supervised practicum for doctoral students in assisting with the supervision of first year students in laboratory and practicum experiences in counseling.
Graduate Staff

History

GRADUATE FACULTY

Professor RALPH W. GREENLAW, *Head*
Professors: BURTON F. BEERS, MARVIN L. BROWN, JR., DORIS E. KING, STUART NOBLIN; *Adjunct Professor:* HOUSTON G. JONES; *Associate Professors:* MURRAY S. DOWNS, ROBERT N. ELLIOTT, WILLIAM C. HARRIS, JOHN M. RIDDLE, STANLEY SUVAL; *Assistant Professors:* DAVID C. BAILEY, JOSEPH P. HOBBS, MARY E. WHEELER

The history department offers a program leading to the Master of Arts degree in history. Although no specific courses are stipulated for admission to the program, preference will be given to those who offer at least 18 hours in history and a total of 30 hours in the social sciences. Candidates are expected to have taken the Aptitude portion of the G.R.E., or if admitted provisionally must do so before the end of their first semester. It is very helpful if candidates will forward a brief statement of their objectives in entering the program along with their application.

Normally a degree candidate will concentrate his work in either European or American history with the required total of 30 hours being made up of nine to twelve hours of course work at the 500 level or above; six hours of research seminar (600 level); up to six hours of research and preparation of thesis (600 level); and six to nine hours of course work in a field related to the candidate's area of concentration (500 or 600 level). Under special circumstances a candidate may be permitted to include a 400 level course in his program if it has particular relevance to his program objectives.

Candidates concentrating in American history have the advantage of the excellent source materials available nearby at the State Department of History and Archives. It should be noted that a candidate's degree program can include a two-semester sequence in the history and administration of archives, a field in which there is considerable demand for well-trained people at this time. For master's candidates interested in teaching in the public schools, the education and other courses required for the state certificate are available, but inclusion of these will in most cases extend the time needed for the degree to three or four semesters.

Although no fellowships are offered at this time, some limited financial assistance is available and inquiry concerning this should be addressed to the head of the department, 161 Harrelson Hall.

FOR ADVANCED UNDERGRADUATES

HI 401 HISTORY OF RUSSIA TO 1881 3(3-0) F
Prerequisite: HI 101-102 or equivalent with consent of instructor

This course surveys the history of Russia from its origins through the great reforms (mid-19th century) with emphasis on the political, religious and cultural trends that underlie the development of the Russian state and society during this period.

HI 402 HISTORY OF RUSSIA SINCE 1881 3(3-0) S
Prerequisite: HI 101 102 or equivalent with consent of instructor

This course surveys the history of Russia and the Soviet Union from the great reforms of the 19th century to modern times, with emphasis on the political,

religious and cultural trends that underlie the development of the Russian state and society and the position of the U.S.S.R. in the world today.

HI 407 FRANCE SINCE THE REVOLUTION 3(3-0) F
Prerequisite: HI 101-102 or equivalent with consent of instructor

An examination of the major trends in French history since the downfall of Napoleon I. Cultural, economic, social and intellectual trends are stressed as well as the political. The ways in which France has been a seedbed for new movements in Europe are particularly noted.

HI 413 UNITED STATES FOREIGN RELATIONS SINCE 1898 3(3-0) F
Prerequisite: HI 111-112 or equivalent with consent of instructor

An examination of the origins of American foreign policy and the conduct of diplomacy in the era since the United States became a world power.

HI 421 ANCIENT AND MEDIEVAL SCIENCE 3(3-0) FS
Prerequisite: HI 101-102 or equivalent with consent of instructor

An introduction to the concepts and theories providing the foundations of science from the classical age until the close of the Middle Ages.

HI 422 RISE OF MODERN SCIENCE 3(3-0) FS
Prerequisite: HI 101-102 or equivalent with consent of instructor

A study of the evolution of science from antiquity to the present with particular attention given to the impact of scientific thought upon selected aspects of western civilization. The course provides a broad perspective of scientific progress and shows the interrelationship of science and major historical developments.

HI 427 EUROPEAN INTELLECTUAL HISTORY 3(3-0) F
Prerequisite: HI 101-102 or equivalent with consent of instructor

Covering the period since the French Revolution, this course examines major trends in European thought influencing the course of history. Special attention is given to the development of the social sciences. The growth of a distinct intellectual class and the role of its ideas in European political and social life is emphasized.

HI 462 (ED 462) HISTORY OF EDUCATION 3(3-0) S
Prerequisite: HI 101-102 or equivalent with consent of instructor

The course traces the development of educational institutions and practices and analyzes the ideas and influence of educational innovators and critics. Approximately equal time is given to each of the following areas: the Greeks to the Reformation, Modern Europe and the United States.

HI 470 (EC 470) EVOLUTION OF THE AMERICAN ECONOMY 3(3-0) S

(See economics, page 120.)

HI 471 REVOLUTIONARY CHINA 3(3-0)
Prerequisites: HI 263 and HI 264 or consent of instructor

An intensive examination of the destruction of traditional China and the emergence of modern nationalism. (Offered 1971-72 and alternate years.)

HI 472 MODERN JAPAN, 1850 TO PRESENT 3(3-0)
Prerequisites: HI 263 and HI 264 or consent of instructor

An intensive examination of Japan's emergence as a nation and world power. (Offered 1972-73 and alternate years.)

FOR GRADUATES AND ADVANCED UNDERGRADUATES

HI 500 (BS 500) THE DEVELOPMENT OF CONTEMPORARY CONCEPTS IN BIOLOGY 3(3 0) S

(See biological sciences, page 79.)

HI 505 THE ROMAN REVOLUTION, 133 B.C.-27 B.C. 3(3 0) F
Prerequisite: Six hours of European history above the introductory level or consent of department

An analysis of the economic, cultural and political factors which caused a breakdown of the Roman republican constitution. Mr. Riddle

HI 506 HISTORY OF THE ROMAN EMPIRE, 27 B.C.-180 A.D. 3(3-0) S
Prerequisite: Six hours of European history above the introductory level or consent of department

The course traces the evolutionary development of the government of the empire from Augustus through Marcus Aurelius. Mr. Riddle

HI 529 REVOLUTIONARY EUROPE, 1760 1792 3(3-0) F
Prerequisite: Six hours of European history above the introductory level or consent of department

An intensive study of the background of revolutionary ideas and events in Europe during the period indicated. Mr. Greenlaw

HI 530 REVOLUTIONARY EUROPE, 1792-1815 3(3-0) S
Prerequisite: Six hours of European history above the introductory level or consent of department

An intensive study of revolutionary events in France and especially of their impact upon Europe in this period. Mr. Greenlaw

HI 531 HISTORY OF GREAT BRITAIN, 1714-1820 3(3-0) F
Prerequisite: Six hours of European history above the introductory level or consent of department

A study in depth of constitutional, religious and economic ideas and institutions in 18th century Britain. Mr. Downs

HI 532 HISTORY OF GREAT BRITAIN, 1820-1914 3(3-0) S
Prerequisite: Six hours of European history above the introductory level or consent of department

A study in depth of constitutional, religious and economic ideas and institutions of 19th century Britain. Mr. Downs

HI 535 DIPLOMATIC HISTORY OF EUROPE, 1815-1878 3(3-0) F
Prerequisite: Six hours of European history above the introductory level or consent of department

An analysis of the nature of European diplomatic relations from the Congress of Vienna to the Congress of Berlin. Mr. Brown

HI 536 DIPLOMATIC HISTORY OF EUROPE, 1878-1939 3(3-0) S
Prerequisite: Six hours of European history above the introductory level or consent of department

A study of diplomatic history of Europe from the Congress of Berlin through the reemergence of the system of balance of power and the repercussions of imperialism, the diplomatic aspects of the World Wars, and the attempts at solving world problems by means of diplomacy. Mr. Brown

HI 545 THE AMERICAN CIVIL WAR, 1849-65 3(3-0) F
Prerequisite: Six hours of American history

This course traces and analyzes events that led to the disruption of the Union and provides an intensive study of the war, with emphasis upon its nonmilitary aspects. Only the major military campaigns are discussed. Mr. Harris

HI 546 THE UNITED STATES DURING THE RECONSTRUCTION ERA, 1865-1880 3(3-0) S
Prerequisite: Six hours of American history

This course is an in-depth study of the difficulties involved in the restoration and readjustment of American society after the Civil War. Special intention is given to social and economic conditions in the defeated South, military reconstruction and Republican ascendancy in the region. Mr. Harris

HI 549 RECENT U. S. HISTORY, 1912-33 3(3-0) F
Prerequisite: Six hours of American history or consent of department

An intensive examination of the major events in American life in the opening years of the 20th century. Mr. Beers

HI 550 RECENT U. S. HISTORY, 1933-PRESENT 3(3 0) S
Prerequisite: Six hours of American history or consent of department

An intensive examination of the major events in American life in the middle years of the 20th century. Mr. Beers

HI 551 HISTORY AND PRINCIPLES OF THE ADMINISTRATION OF ARCHIVES AND MANUSCRIPTS 3(3-0) F
Prerequisite: Six hours of American history or consent of department

A study of the nature, importance and use of original manuscript resources; the history and evolution of written records and the institutions administering them. Mr. Jones

HI 552 APPLICATION OF PRINCIPLES OF ADMINISTRATION OF ARCHIVES AND MANUSCRIPTS 3(3-0) S
Prerequisite: Six hours of American history or consent of department

Internship training in the application of the principles and practices of archival management. Mr. Jones

HI 561 U. S. FAR EASTERN POLICY, 1842-1922 3(3 0) F
Prerequisite: Six hours of American history or consent of department

A study of the character and development of the basic principles of American policy in the Far East from their origin to their incorporation in treaties at the Washington Disarmament Conference. Mr. Beers

HI 562 U. S. FAR EASTERN POLICY, 1922-PRESENT 3(3-0) S
Prerequisite: Six hours of American history or consent of department

A study of the character and development of the basic principles of American policy in the Far East from the end of World War I to the present. Mr. Beers

HI 563 SOCIAL AND ECONOMIC HISTORY OF THE UNITED STATES TO 1860 3(3-0) F
Prerequisite: Six hours of American history or consent of department

A study of the social and economic ideas and institutions important in American life from the colonial period up to the Civil War. Miss King

HI 564 SOCIAL AND ECONOMIC HISTORY OF THE UNITED STATES SINCE 1860 3(3-0) S
Prerequisite: Six hours of American history or consent of department

A study of the social and economic ideas and institutions important in American life since the beginning of the Civil War. Miss King

HI 565 THE HISTORY OF URBAN LIFE IN THE UNITED STATES, 1607-1865 3(3-0) F
Prerequisite: Six hours of U. S. history including HI 111 or consent of instructor

The history of urban life in the United States before 1865. This course is designed primarily to give the student an understanding of the historical background of urban life in the United States before 1865. Miss King

HI 566 THE HISTORY OF URBAN LIFE IN THE UNITED STATES, 1865-PRESENT 3(3-0) S
Prerequisite: Six hours of U. S. history including HI 112 or consent of instructor

The history of urban life in the United States, from 1865 to present. This course is designed primarily to give the student an understanding of the historical background of today's urban problems. Miss King

HI 571 HISTORY OF SOVIET RUSSIA TO 1930 3(3-0) F
Prerequisite: Six hours of European history above the introductory level or consent of department

An analysis of the origins and effects of the 1917 revolutions and the domestic and foreign policies of the new Soviet regime to 1930. Mrs. Wheeler

HI 572 HISTORY OF SOVIET RUSSIA SINCE 1930 3(3-0) S
Prerequisite: Six hours of European history above the introductory level or consent of department

An analysis of the domestic and foreign policies of the Soviet Union since 1930 with special emphasis on the period since 1945. Mrs. Wheeler

FOR GRADUATES ONLY

HI 601 HISTORIOGRAPHY AND HISTORICAL METHOD 3(3-0) F
Prerequisite: Open only to graduate students in history

A study of the major steps in the development of historical investigation and writing from classical times to the present, as well as an analysis of the elements of good historical research and writing with some discussion of the methodology used by the contemporary scholarly historian. Graduate Staff

HI 602 SEMINAR IN AMERICAN HISTORY 3(3-0) S
Prerequisite: Open only to graduate students in history

A small research seminar on special topics in American history. Graduate Staff

HI 604 SEMINAR IN EUROPEAN HISTORY 3(3-0) S
Prerequisite: Open only to graduate students in history

A small research seminar on special topics in European history. Graduate Staff

HI 606 SEMINAR IN DIPLOMATIC HISTORY 3(3-0) S
Prerequisite: Open only to graduate students in history

A small research seminar on topics in diplomatic history. Mr. Brown

HI 699 RESEARCH IN HISTORY — Credits Arranged
Prerequisite: Open only to graduate students in history
Individual research under graduate thesis supervisor. — Graduate Staff

Horticultural Science

GRADUATE FACULTY

Professor CLIVE W. DONOHO, JR., *Head*
Professors: WALTER E. BALLINGER, FRED D. COCHRAN, GENE J. GALLETTA, FRANK L. HAYNES, JR., ROY A. LARSON, CONRAD H. MILLER, RICHARD L. SAWYER; *Research Professors:* JOHN M. JENKINS, JR., DANIEL T. POPE; *Professor USDA:* LEATON J. KUSHMAN; *Visiting Professor:* DAMON BOYNTON; *Associate Professors:* THOMAS F. CANNON, FRANKLIN E. CORRELL, ROBERT C. HALFACRE, WARREN R. HENDERSON, THOMAS R. KONSLER, RICHARD L. LOWER, PAUL V. NELSON, DONALD C. ZEIGER; *Extension Associate Professor:* WALTER A. SKROCH; *Assistant Professors:* THOMAS J. MONACO, C. RICHARD UNRATH; *Extension Assistant Professor:* C. M. MAINLAND

ASSOCIATE MEMBERS OF THE DEPARTMENT

Professors: ROBERT AYCOCK, ROBERT J. DOWNS, ROBERT H. MOLL, THOMAS J. SHEETS, RICHARD J. VOLK

Graduate study in horticultural science may enable the student to qualify for the Master of Science or the Doctor of Philosophy degrees. Areas of study and research include plant physiology, plant breeding and genetics, post-harvest physiology, plant nutrition, growth regulators, and weed science involving all horticultural crops. The professional degrees, Master of Horticulture and Master of Agriculture, can be earned by students who do not plan further graduate study and want to substitute additional course work for the research requirement in their graduate study.

The department has an outstanding faculty and excellent facilities for directing graduate programs. The greenhouse range, one of the best teaching and research facilities in the nation, covers over 41,400 square feet and 21 sections, each containing individual temperature and light control equipment. Also, the Phytotron is available for graduate research involving controlled environmental studies on horticultural crops. Laboratory facilities include four analytical laboratories, two cytological and anatomical laboratories, one soil testing laboratory for greenhouse control, one radioisotope laboratory and one landscape laboratory. Post-harvest facilities include 14 controlled temperature storage rooms and grading, washing and packaging equipment. These combined facilities provide a wide variety of opportunities in basic and technical research in the horticultural field. An extensive and varied assortment of plant materials is available for use in graduate programs.

The great differences in climate and soils in North Carolina, from the coast to the mountains, make possible the study of plant responses under numerous conditions. Land and facilities for horticultural research are available on 10 of the outlying experiment stations located throughout North Carolina.

The opportunities for employment after advanced training include faculty teaching and research positions in state and privately endowed educational institutions; research and regulatory positions with the United States Department of Agriculture, both foreign and domestic; extension specialists and county agents; research, production and promotional work with agribusiness, concerned with production of horticultural crops or services to horticultural industries.

The department has a number of graduate assistantships at stipends adjusted to the previous training and experience of the recipients. These include commercial assistantships, National Defense Education Act fellowships, Agricultural Foundation assistantships and Experiment Station assistantships. Information provided on the application for admission to the Graduate School will be used to evaluate prospective students as recipients for research and teaching assistantships.

FOR ADVANCED UNDERGRADUATES

HS 411 NURSERY MANAGEMENT 3(2-3) F
Prerequisites: BS 100, SSC 200

The principles and practices involved in the production, management and marketing of field grown and container grown nursery plants. Field trips will be taken.

HS 414 RESIDENTIAL LANDSCAPING 4(2-6) F
Prerequisites: SSC 220, HS 211, HS 212

The landscape planning and development of residential properties to create an aesthetical and functional landscape composition to complement the home. Students will be required to complete planting plans, including design, plant lists, planting details and technical specifications.

HS 421 FRUIT PRODUCTION 3(2-3) F
Prerequisites: BS 100, SSC 200

A study of identification, adaptation and methods of production and marketing of the principal trees and small fruits. Modern practices as related to selection of sites, nutritional requirements, management practices and marketing procedures will be discussed. (Offered 1973 74 and alternate years.)

HS 432 VEGETABLE PRODUCTION 3(2-3) F
Prerequisites: BS 100, SSC 200

A study of the origin, importance, distribution, botanical relationships and principles of production and marketing of the major vegetable crops. (Offered 1972 73 and alternate years.)

HS 441 FLORICULTURE I 3(2-3) F
Prerequisites: BS 100, SSC 200

The scope and importance of the commercial flower industry; the basic principles and practices involved in the production and marketing of flowers grown in the greenhouse and in the field. (Offered 1973-74 and alternate years.)

HS 442 FLORICULTURE II 3(2-3) S
Prerequisites: BS 100, SSC 200

Principles and methods of production of commercial flower crops in the greenhouse and in the field, including fertilization, moisture, temperature and light relationships, insect and disease control, and marketing of cut flowers and pot plants. (Offered 1973-74 and alternate years.)

HS 471 ARBORICULTURE 3(2-2) S
Prerequisites: BS 100, SSC 200

A study of the principles and practices in the care and maintenance of ornamental trees and shrubs, such as pruning, fertilization, control of insects and diseases, and tree surgery. Field trips will be taken. (Offered 1973-74 and alternate years.)

HS 491 SENIOR SEMINAR 1(1-0) F
Prerequisite: Consent of department

Presentation of scientific articles, progress reports in research and special problems in horticulture and related fields.

FOR GRADUATES AND ADVANCED UNDERGRADUATES

HS 514 (CS 514) PRINCIPLES AND METHODS IN WEED SCIENCE 3(2-2) S
Prerequisites: CS 414 or equivalent

Studies on the losses caused by weeds, the ecology of weeds, biological control, basic concepts of weed management, herbicide-crop relationships and herbicide development. Introduction to greenhouse and bioassay techniques used in herbicide work and to field research techniques supplemented by laboratory and field exercises. Mr. Monaco

HS 521 (FS 521) FOOD PRESERVATION 3(2-3) F

(See food science, page 159.)

HS 541 (CS 541, GN 541) PLANT BREEDING METHODS 3(3-0) F

(See crop science, page 112.)

HS 542 (CS 542, GN 542) PLANT BREEDING FIELD PROCEDURES 2(0-4) Sum.

(See crop science, page 113.)

HS 552 GROWTH OF HORTICULTURAL PLANTS 3(2-3) F
Prerequisite: BO 421

A study of the effect of air pollutants, CO_2 enrichment, water, light, temperature and growth substances on growth and development of horticultural plants.
Graduate Staff

HS 562 (FS 562) POST-HARVEST PHYSIOLOGY 3(3-0) S
Prerequisite: BO 421

A study of chemical and physiological changes that occur during handling, transportation and storage which affect the quality of horticultural crops. Consideration will be given to preharvest and post-harvest conditions which influence these changes. Mr. Ballinger

HS 599 RESEARCH PRINCIPLES Credits Arranged
Prerequisite: Consent of instructor Maximum 6

Investigation of a problem in horticulture under the direction of the instructor. The students obtain practice in experimental techniques and procedures, critical review of literature and scientific writing. The problem may last one or two semesters. Credits will be determined by the nature of the problem, not to exceed a total of three hours for any one problem. A written report and final oral exam required for completion of course. Graduate Staff

FOR GRADUATES ONLY

HS 613 (CS 613, GN 613) PLANT BREEDING THEORY 3(3-0) S

(See crop science, page 113.)

HS 614 (CS 614, SSC 614) HERBICIDE BEHAVIOR IN PLANTS AND SOILS 3(3-0) F

(See crop science, page 113.)

HS 621 METHODS AND EVALUATION OF HORTICULTURAL RESEARCH 3(3-0) F
Prerequisite: Graduate standing

Principles and methods of research in the field of horticulture and their application to the solution of current problems. Critical study and evaluation of scientific publications. Compilation, organization and presentation of data. Graduate Staff

HS 622 MINERAL NUTRITION IN PLANTS 3(2-3) S
Prerequisites: BO 551, BO 552

A comprehensive study of the functional roles of nutrients essential to plant growth, their interrelationships and their mode of influence on quality indices of horticultural crops. Considerations of the complexity of mineral nutrition experimentation and evaluation of results. Recent developments in nutrient sources. A detailed look at the establishment and application of foliar analysis, foliar fertilization, and the nutrient uptake process in plants. (Offered 1973-74 and alternate years.) Mr. Nelson

HS 691 SEMINAR 1(1-0) FS
Prerequisite: Graduate standing
Required of all horticultural science graduate students.

Presentation of scientific articles and special lectures. Students will be required to present one or more papers. Graduate Staff

HS 699 RESEARCH Credits Arranged
Prerequisites: Graduate standing in horticulture, consent of advisory committee chairman

A maximum of six credits is allowed toward the Master of Science degree; no limitation on credits in doctoral program.

Original research on specific problems in fruit, vegetable and ornamental crops. Graduate Staff

Industrial and Technical Education

GRADUATE FACULTY

Professor DURWIN M. HANSON, *Head*
Professors: JOSEPH T. NERDEN, DELMAR W. OLSON, *Coordinator, Graduate Studies in Industrial Arts; Associate Professor:* TALMAGE B. YOUNG; *Assistant Professors:* THOMAS C. SHORE, FARMER S. SMITH; *Adjunct Assistant Professor:* WILLIAM A. MCINTOSH

The Department of Industrial and Technical Education offers graduate work leading to the degrees of Master of Science, Master of Education and Doctor of

Education. The rapid development of industrial arts education and industrial and technical education in North Carolina and throughout the nation provides many opportunities for teachers, supervisors and administrators who have earned advanced degrees.

The facilities at the University afford an excellent program of supporting courses at the graduate level in the related fields of science, mathematics, guidance and personnel services, psychology, sociology, economics, statistics, computer science and engineering. The prerequisite for graduate work in the Department of Industrial and Technical Education is a proficiency in the undergraduate courses required for the bachelor's degree in industrial arts education, industrial or technical education, or a substantial equivalent.

A limited number of teaching and research assistantships and fellowships are available for qualified graduate students.

FOR GRADUATES AND ADVANCED UNDERGRADUATES

ED 516 COMMUNITY OCCUPATIONAL SURVEYS 2(2-0) S
Prerequisites: Six hours in education, consent of instructor

Methods in organizing and conducting local and regional surveys, and procedures in making evaluations of the data gathered in these surveys for the planning of programs of vocational and technical education. Economic, sociological and other demographic factors are explored, and procedures for obtaining valid data concerning these factors are studied. Mr. Hanson

ED 517 IMPLICATIONS FOR DATA PROCESSING IN EDUCATION 3(3-0) FS
Prerequisites: CSC 111; ED 529

An intensive study of current attempts to apply new technologies to education. Attention will be given to research findings related to computer assisted instruction, gamed instructional simulation, approaches to guidance and prescription learning as well as administrative problems pertaining to student scheduling, pupil transportation and data reporting systems. Graduate Staff

ED 518 PRINCIPLES OF SCHOOL LAW 3(3 0) FS
Prerequisite: Six hours graduate credit

This course will be an intensive study of the legal rights, duties, privileges and responsibilities entailed in the educational enterprise. It will cover the essentials of school law in such a way that the student will be able to obtain both a general understanding of the processes of law as they affect American education and also important specific legal aspects which affect vocational education. Included are the secondary, post-secondary and adult vocational education laws and their implications. Messrs. Nerden, Law

ED 525 TRADE ANALYSIS AND COURSE CONSTRUCTION 3(3-0) F
Prerequisites: ED 344, PSY 304

Principles and practices in analyzing occupations for the purpose of determining teaching content. Practice in the principles underlying industrial and technical course organization based on occupational analyses covering instruction in skills and technology and including course outlines, job sequences, the development of instructional materials and schedules. Mr. Hanson

ED 527 PHILOSOPHY OF INDUSTRIAL AND TECHNICAL EDUCATION 3(3 0) F
Prerequisites: ED 422, ED 440

A presentation of the historical development of industrial and technical education

in relation to the broad field of vocational education; philosophies of vocational education and the resulting types of programs; trends and problems related to vocational-industrial education; study of local, state and federal legislation which pertains to vocational education. Messrs. Hanson, Nerden

ED 529 CURRICULUM MATERIALS DEVELOPMENT 3(3-0) FS
Prerequisite: ED 525

This course deals with the procedures used in analyzing skills, technical knowledge and general education which has a bearing upon the ultimate development of curriculum for programs of vocational education. Emphasis is placed upon the selection and organization of curricula used in vocational and technical education, and also the development of curricula and instructional materials. Mr. Hanson

ED 591 SPECIAL PROBLEMS IN INDUSTRIAL EDUCATION Maximum 6
Prerequisites: Six hours graduate work, consent of department head

Directed study, other than a thesis problem, in order to provide individualized instruction and analysis in a specialized area of industrial or technical education. Under guidance, the graduate student may select a problem which has equal value from the standpoint of scholarship and utilitarian purposes, and develop the problem into a practical document. Messrs. Hanson, Nerden

FOR GRADUATES ONLY

ED 608 SUPERVISION OF VOCATIONAL AND INDUSTRIAL ARTS EDUCATION 3(3-0) F

(See education, page 131.)

ED 609 PLANNING AND ORGANIZING TECHNICAL EDUCATIONAL PROGRAMS 3(3-0) FS
Prerequisites: ED 344, ED 420, ED 440, ED 516, PSY 304

Principles of planning and procedures in organizing programs of vocational and technical education, especially those dependent upon state and federal legislation. Professional course for coordinators and directors of local systems of vocational education, and for supervisors and administrators of vocational and technical programs on the county, regional and state levels. Emphasis is placed upon the organization of high school, post-high school and adult technical education programs. Course includes a survey of educational needs, plans for constructing, equipping and maintaining buildings, with special attention given to the financing of the program of technical education, the staffing and management aspects.
Messrs. Hanson, Nerden

ED 610 ADMINISTRATION OF VOCATIONAL AND INDUSTRIAL ARTS EDUCATION 3(3-0) S

(See education, page 131.)

ED 611 LAWS, REGULATIONS AND POLICIES AFFECTING VOCATIONAL EDUCATION 3(3-0) FS
Prerequisites: ED 527, ED 610 or equivalent

A detailed study of legislation (national and state) which applies directly to vocational education. Basic social and economic issues which precipitated the legislation are studied in depth; also the socioeconomic impact of the legislation is reviewed. Emphasis is placed upon the organizational structure and the operating policies under which national and state legislation is converted into programs of vocational and technical education. Mr. Nerden, Graduate Staff

ED 612 FINANCE, ACCOUNTING AND MANAGEMENT OF VOCATIONAL EDUCATION PROGRAMS 3(3-0) FS
Prerequisites: ED 527, ED 610 or equivalent

A detailed study of the factors which affect the financing of programs of vocational education. Special emphasis is placed upon the social, economic, political and power factors which impinge upon the procedures which are generally followed in financing vocational and technical education. Study is made of the matter of financing new vocational enterprises, as well as the study of the continuing costs of established programs. Costs of operation, procedures for the purchase of equipment, costs of new building construction and other aspects of finance in vocational education are studied in detail. Mr. Nerden, Graduate Staff

ED 630 PHILOSOPHY OF INDUSTRIAL ARTS 2(2-0) FS
Prerequisite: Twelve hours of education
Required of all graduate students in industrial arts education.

Current and historical developments in industrial arts; philosophical concepts, functions, scope, criteria for the selection and evaluation of learning experiences, laboratory organization, student personnel program, community relationships, teacher qualifications and problems confronting the industrial arts profession.
Graduate Staff

ED 635 ADMINISTRATION AND SUPERVISION OF INDUSTRIAL ARTS 2(2-0) FS
Prerequisite: Twelve hours of education

A study of the problems and techniques of administration and supervision in the improvement of industrial arts in the public schools. Selection of teachers and their improvements in service, and methods of evaluating industrial arts programs.
Mr. Young

ED 691 SEMINAR IN INDUSTRIAL EDUCATION 1(1-0) FS
Prerequisite: Graduate standing or consent of instructor

Reviews and reports of topics of special interest to graduate students in industrial and technical education. The course will be offered in accordance with the availability of distinguished professors, and in response to indicated needs of the graduate students. Mr. Hanson

ED 692 SEMINAR IN INDUSTRIAL ARTS EDUCATION 1(1-0) FS
Prerequisite: Graduate standing

Reviews and reports on special topics of interest to students in industrial arts education. Graduate Staff

Industrial Arts

FOR GRADUATES AND ADVANCED UNDERGRADUATES

IA 510 DESIGN FOR INDUSTRIAL ARTS TEACHERS 3(2-2) Sum.
Prerequisites: Six hours of drawing, IA 205 or equivalent

A study of new developments in the field of design with emphasis on the relationship of material and form in the selection and designing of industrial arts projects.
Graduate Staff

IA 560 (ED 560) NEW DEVELOPMENTS IN INDUSTRIAL ARTS EDUCATION 3(3 0) Sum.
Prerequisites: Twelve hours of education and teaching experience

This course is a study of the new developments in industrial arts education. It is

designed to assist teachers and administrators in developing new concepts and new content based on the changes in technology. They will be required to reevaluate their programs in the light of these new concepts and the new content.
Mr. Olson, Graduate Staff

IA 590 LABORATORY PROBLEMS IN INDUSTRIAL ARTS Maximum 6
Prerequisites: Senior standing, consent of instructor

Courses based on individual problems and designed to give advanced majors in industrial arts education the opportunity to broaden or intensify their knowledge and abilities through investigation and research in the various fields of industrial arts, such as metals, plastics, ceramics or electricity-electronics. Graduate Staff

IA 592 SPECIAL PROBLEMS IN INDUSTRIAL ARTS Maximum 6
Prerequisite: One term of student teaching or equivalent

The purpose of this course is to broaden the subject matter experiences in the areas of industrial arts. Problems involving curriculum, investigation or research in one or more industrial arts areas will be required. Graduate Staff

IA 595 (ED 595) INDUSTRIAL ARTS WORKSHOP 3(3-0) Sum.
Prerequisite: One or more years of teaching experience

A course for experienced teachers, administrators and supervisors of industrial arts. The primary purpose will be to develop sound principles and practices for initiating, conducting and evaluating programs in this field. Enrollees will pool their knowledge and practical experiences and will do intensive research work on individual and group problems. Graduate Staff

FOR GRADUATES ONLY

IA 645 TECHNOLOGY AND INDUSTRIAL ARTS 3(3-0) FS
Prerequisites: IA 560, ED 630

Technology: its nature, origins, advance. Impact of technological advance on man and culture. Technology as the material culture. Changing concepts of work, skill, occupations, discretionary time. Technology and its relation to industrial arts education. Mr. Olson

IA 660 (ED 660) INDUSTRIAL ARTS CURRICULUM 3(3-0) FS
Prerequisite: IA 645

Industrial arts curriculum origins, analysis, organization, evaluation, revision. Subject matter derivation and classification applicable to all levels of instruction. Relationships among curriculum, philosophy and methodology. Mr. Olson

Industrial Engineering

GRADUATE FACULTY

Professor CLIFTON A. ANDERSON, *Head*
Professors: JOHN R. CANADA, ROBERT G. CARSON, JR., SALAH E. ELMAGHRABY, ROBERT W. LLEWELLYN, RICHARD G. PEARSON; *Associate Professors:* RAUL E. ALVAREZ, RICHARD H. BERNHARD, JOHN J. HARDER, AMIN M. KAMAL, ANCO L. PRAK, STANLEY M. SOLIDAY; *Assistant Professors:* GERALD E. BENNINGTON, MICHAEL J. MAGAZINE, HENRY L. W. NUTTLE; *Visiting Assistant Professor:* MAHMOUD A. AYOUB

The department offers programs of graduate study leading to the Master of Science, Master of Industrial Engineering and the Doctor of Philosophy degrees. While each individual student's plan of study is specifically tailored to meet his own personal desires and professional needs, the departmental course offerings stress two main themes of industrial engineering. These focal points are quantitative decision making, and human factors and work systems design. Each candidate is expected to include within his study plan, one or more minor areas of study. Typical minors are taken in statistics, economics, mathematics, psychology and other engineering disciplines.

Industrial engineering is concerned with the solutions to problems relating to the workings of complex organizational systems, such as industrial corporations or governmental agencies as they seek to furnish goods and/or services to the public. Where the work under study requires the commitment of substantial resources and the coordination of varied activities that are both unpredictable and unstable, solution to the problem requires sophisticated methods. There are opportunities for many types of research including solution to problems in production planning and scheduling, networks, inventory, line balancing and simulation. Research relating to human factors may include problems in the design of man-machine systems, the study of human performance characteristics, biomechanics, work physiology and systems safety.

The Master of Science program, which requires a thesis, is intended for the student who is preparing for a career in research and related work. The Master of Industrial Engineering program which does not require a thesis is focused on applications and the study and solution of practical problems. An off-campus program conducted in cooperation with UNC-Greensboro is provided for qualified personnel from the Greensboro, N. C. area. Courses are conducted on the Greensboro campus in the evenings thereby enabling students to earn the Master of Industrial Engineering degree through part-time study.

The University provides access to an outstanding computer capability. This includes an IBM System/370, Model 165 computer at the Research Triangle with a Model 40 remote terminal on the N. C. State campus. Facilities for human re search include special laboratories for environmental factors, biomechanics and work physiology, and performance assessment display systems evaluation. Interests in the areas of occupational safety and health can be supported by a new traineeship program in "system safety engineering" or by collaboration with the nearby Highway Safety Research Center. Those other departments from which a student may choose his minor cooperate in interdisciplinary research projects and make their facilities available to industrial engineering graduate students.

Applicants desiring financial aid may express interest in graduate fellowships, teaching assistantships or research assistantships as supported by a number of active projects in the department. Support for such awards currently comes from a variety of sources including industry, the National Science Foundation, National Aeronautics and Space Administration, Department of Defense and the U. S. Public Health Service, as well as from State funds.

In order to be considered for certain fellowship awards the applicant must submit scores on the Graduate Record Examination. In the case of interdisciplinary programs, competition for awards can be expected from applicants in departments which require GRE scores. Therefore, all applicants for financial support are strongly encouraged to supply these scores. For those desiring admission to the doctoral program, again, submission of the GRE scores can be expected to enhance the probability of acceptance.

FOR ADVANCED UNDERGRADUATES

IE 401 INDUSTRIAL ENGINEERING ANALYSIS I 3(3-0) FS
Prerequisites: IE 361, MA 405

A study of linear programming methods and their applications in industrial engineering; the transportation method with applications to scheduling in transportation and production problems; the simplex method and its applications in production planning, production scheduling and allied fields; upper bound, integer, parametric and primal dual methods with their typical applications; the interrelationships between linear programming and game theory.

IE 402 INDUSTRIAL ENGINEERING ANALYSIS II 3(3-0) F
Prerequisite: IE 401

An introductory study of several aspects of operations research methods with emphasis on their industrial engineering applications; replacement theory, sequencing problems, inventory control methods and dynamic programming and their applications.

IE 403 INDUSTRIAL ENGINEERING ANALYSIS III 3(3-0) S
Prerequisite: IE 401

An introductory study of several aspects of operations research methods with emphasis on their industrial engineering applications; continuous and discrete cybernetics with emphasis on Markov processes; finite and infinite queuing models; industrial control methods and industrial dynamics.

IE 408 PRODUCTION CONTROL 3(3 0) S
Prerequisites: IE 361, IE 401

Forecasting, production planning, models for scheduling and sequencing, inventory models and operational systems, as well as the reporting and evaluation functions necessary for the design and control of a production system will be discussed. Application of quantitative methods to these areas of application will be emphasized.

IE 421 DATA PROCESSING AND PRODUCTION CONTROL SYSTEMS 3(3-0) S
Prerequisites: IE 352, CSC 111

This course is an introduction to the design of integrated control systems necessary for effective management of production. It will include the methods of systems design, the basic concepts of computer processing systems, the design of control procedures and reports, and their application to mechanized and electronic data processing equipment. Major emphasis will be placed on the design of control procedures for production scheduling, labor performance and quality control. Systems flow charts, block diagrams and program statements in compiler form will be used for each system application.

IE 453 OPERATIONS PLANNING AND PLANT LAYOUT 3(2-3) F
Prerequisite: IE 352

This course will provide an opportunity for the student to apply the basic principles contained in the prerequisite course to the design of plantwide production programs with emphasis placed on planning, arrangement, layout and implementation of such programs. It will include operations sequencing, tooling and equipment selection, materials handling, systems design, manpower and facilities forecasting. Suitable cases will be drawn from both mass production and jobbing operations.

FOR GRADUATES AND ADVANCED UNDERGRADUATES

IE 505 (MA 505, OR 505) MATHEMATICAL PROGRAMMING I 3(3-0) F Sum.
Prerequisite: MA 405

A study of mathematical methods applied to problems of planning. Linear programming will be covered in detail. This course is intended for those who desire to study this subject in depth and detail. It provides a rigorous and complete development of the theoretical and computational aspects of this technique as well as a discussion of a number of applications. Graduate Staff

IE 509 (OR 509) DYNAMIC PROGRAMMING 3(3-0) S Sum.
Prerequisites: MA 405, ST 421

An introduction to the theory and computational aspects of dynamic programming and its application to sequential decision problems. Messrs. Elmaghraby, Nuttle

IE 511 ADVANCED ENGINEERING PROJECT ANALYSIS 3(3-0) F
Prerequisites: IE 311, ST 421

Analysis of project economy models with certainty assumed, advantages and limitations of models, effects of income tax and depreciation methods. Risk analyses employing probability concepts, sensitivity studies and measures of utility. Estimation techniques and use of accounting information, time series analysis and judgment factors. Planning and uses of capital funds. Messrs. Bernhard, Canada

IE 515 PROCESS ENGINEERING 3(3-0) F
Prerequisites: IE 328, IE 443

The technical process of translating product design into a manufacturing program. The application of industrial engineering in the layout, tooling, methods, standards, costs and control functions of manufacturing. Laboratory problems covering producer and consumer products. Mr. Harder

IE 517 AUTOMATIC PROCESSES 3(3-0) S
Prerequisites: IE 328, IE 443

Principles and methods for automatic processing. The design of product, process and controls. Economic, physical and sociological effects of automation. Mr. Harder

IE 521 CONTROL SYSTEMS AND DATA PROCESSING 3(3-0) S
Prerequisite: IE 421

This course presents the problems and techniques required for systematic control of the production process and the business enterprise. This includes the determination of control factors, the collection and recording of data, and the processing, evaluation and use of data. The course will illustrate the applications and use of data processing equipment and information machines in industrial processes. Case problems will be used extensively. Mr. Llewellyn

IE 522 (OR 522) DYNAMICS OF INDUSTRIAL SYSTEMS 3(3 0) F
Prerequisite: IE 421

A study of the dynamic properties of industrial systems; introduction to servomechanism theory as applied to company operations. Simulation of large nonlinear, multiloop, stochastic systems on a digital computer; methods of determining modifi cations in systems design and/or operating parameters for improved system behavior. Mr. Llewellyn

IE 523 INVENTORY CONTROL METHODS I 3(3 0) S
Prerequisites: ST 421, ST 515, OR 501

A study of inventory policy with respect to reorder sizes, minimum points and

production schedules. Simple inventory models, models with restrictions, price breaks, price changes, analysis of slow-moving inventories. Introduction to the smoothing problems in continuous manufacturing. Applications of linear and dynamic programming. Mr. Alvarez

IE 540 (PSY 540) HUMAN FACTORS IN SYSTEMS DESIGN 3(3-0) S
Prerequisites: IE 338 (PSY 338), ST 513 or ST 515 or consent of instructor

Introduction to problems of the systems development cycle, including man-machine function allocation, military specifications, display-control compatibility, the personnel subsystem concept and maintainability design. Detailed treatment is given to man as an information processing mechanism. Mr. Pearson

IE 541 RESEARCH METHODS IN ACCIDENT STUDY 3(2-2) F
Prerequisites: IE 338 (PSY 338), ST 421

Consideration of the methods used in accident-injury study, including field investigation, experimental engineering and biomedical research, statistical studies and computer simulation. Mr. Ayoub

IE 546 ADVANCED QUALITY CONTROL 3(3-0) S
Prerequisites: IE 353, ST 421

The statistical foundations of quality control are emphasized as well as its economic implications. Mathematical derivations of most of the formulas used are given. Sampling techniques are treated extrensively and many applications of this powerful technique are explained. Graduate Staff

IE 547 ENGINEERING RELIABILITY 3(3-0) F
Prerequisites: IE 353, ST 421

The methodology of reliability including application of discrete and continuous distribution models and statistical designs; reliability estimation, reliability structure models, reliability demonstration and decision, and reliability growth models. Example of reliability evaluation and demonstration programs.
Graduate Staff

IE 561 (OR 561) QUEUES AND STOCHASTIC SERVICE SYSTEMS 3(3-0) F
Prerequisite: MA 421

General concepts of stochastic processes are introduced. Poisson processes, Markov processes and renewal theory are presented. These are then used in the analysis of queues, starting with a completely memoryless queue to one with general parameters. Applications to many engineering problems will be considered.
Mr. Magazine

IE 586 (OR 586) NETWORK FLOWS 3(3-0) S
Prerequisite: IE 505 or equivalent

This course will study problems of flows in networks. These problems will include the determination of the shortest chain, maximal flow and minimal cost flow in networks. The relationship between network flows and linear programming will be developed as well as problems with nonlinear cost functions, multi-commodity flows and the problem of network synethesis. (Offered in alternate years.)
Mr. Bennington

IE 591 PROJECT WORK 2-6
Prerequisite: Graduate or senior standing

Investigation and report on an assigned problem for students enrolled in the fifth-year curriculum in industrial engineering. Graduate Staff

FOR GRADUATES ONLY

IE 608 LINEAR PROGRAMMING APPLICATIONS 3(3-0) S
Prerequisite: IE 505 (MA 505, OR 505) or EC 555

The application of linear programming to large problems of a practical nature; product mix, diet, scheduling and blending problems; problem generation, control of accuracy, report generation. Stress is laid on post-optimal studies; multiple-objective functions and right-hand sides; parametric programming on the right-hand side, the objective function, the rim and the interior. Decomposition of various types of problems will receive considerable attention with extensions into some nonlinear systems. (Offered in alternate years.) Mr. Llewellyn

IE 611 THE DESIGN OF PRODUCTION SYSTEMS 3(3-0) F
Prerequisites: IE 505 (MA 505, OR 505), OR 501

The study of production systems: the model, the criterion, decision making and optimization, levels of decision. The graphic representation of systems: signal flow graphs, activity analysis, networks of flow models. The machine assignment problem, scheduling and sequencing, line balancing location-allocation of new facilities. The use of computers in the design of production systems. (Offered in alternate years.) Mr. Elmaghraby

IE 622 INVENTORY CONTROL METHODS II 3(3-0) F
Prerequisite: IE 523

A continuation of IE 523; stochastic inventory systems of lot size-reorder type; periodic review and single period models. Application of dynamic programming theory to deterministic and stochastic cases. Mr. Nuttle

IE 640 (PSY 640) SKILLED OPERATOR PERFORMANCE 3(3-0) F
Prerequisites: IE 540 (PSY 540) or consent of instructor

Theories of the human operator are considered with regard to the classical problems of monitoring, vigilance and tracking. Factors such as biological rhythm, sleep loss, sensory restriction, environmental stress and time-sharing are considered as they interact with and determine overall systems efficiency. (Offered in alternate years.) Mr. Pearson

IE 641 BIOTECHNOLOGY IN SYSTEMS ENGINEERING 3(3-0) F
Prerequisites: IE 540 (PSY 540) or consent of instructor, ZO 421 recommended

Study of major problem areas, methodology, theory and experimental work in biotechnology; interaction among engineering, biological and behavioral factors in design for safety and survival; physiology and biomechanics of acceleration, deceleration and pressure altitude; consideration of operator effectiveness in submarine, extraterrestrial, arctic and desert environments; techniques in evalua tion of crash dynamics and pathology; closed-ecological systems. (Offered in alternate years.) Mr. Soliday

IE 651 SPECIAL STUDIES IN INDUSTRIAL ENGINEERING Credits Arranged
Prerequisite: Graduate standing

The purpose of this course is to allow individual students or small groups of students to undertake studies of special areas in industrial engineering which fit into their particular program and which may not be covered by existing industrial engineering graduate level courses. The work would be directed by a qualified staff member who has particular interest in the area covered by the problem. Such problems may require individual research and initiative in the application of industrial engineering training to new areas or fields. Graduate Staff

IE 692 (OR 692, MA 692) SPECIAL TOPICS IN MATHEMATICAL PROGRAMMING 3(3-0) FS Sum.
Prerequisite: IE 505 (MA 505, OR 505)

The study of special advanced topics in the area of mathematical programming. New techniques and current research in this area will be discussed. The faculty responsible for this course will select the areas to be covered during the semester according to their preference and interest. This course will not necessarily be taught by an individual faculty but can, on occasion, be a joint effort of several faculty members from this University as well as visiting faculty from other institutions. To date, a course on Theory of Networks and another on Integer Programming have been offered under the umbrella of this course. It is anticipated that these two topics will be repeated in the future together with other topics. Graduate Staff

IE 693 SEMINAR IN SYSTEMS SAFETY ENGINEERING 1(1-0) FS
Prerequisites: IE 540 (PSY 540), ST 515

Discussion of contemporary issues involving the systems approach to accident prevention and injury control. History of safety research; federal health, industrial and military activities in safety; current centers of safety research and their activity. Messrs. Pearson, Ayoub

IE 694 ADVANCED PROBLEMS IN HUMAN FACTORS ENGINEERING 3(3-0) FS Sum.
Prerequisites: IE 540 (PSY 540), ST 515

Exploration in depth of a problem area of contemporary interest involving the man-machine-environment interface. Class discussion and analysis of research and theory, with special focus on the human factors aspects of systems design and operation. Messrs. Pearson, Soliday, Ayoub

IE 695 SEMINAR 1(1-0) FS

Seminar discussion of industrial engineering problems for graduate students. Case analyses and reports. Messrs. Elmaghraby, Magazine

IE 699 INDUSTRIAL ENGINEERING RESEARCH Credits Arranged FS Sum.

Graduate research in industrial engineering for thesis credit. Graduate Staff

International Development

Professor JACKSON RIGNEY, *Dean*

There is no question but that America's need for trained personnel for service in foreign countries will increase greatly during the coming years. The world is moving inexorably toward greater interchange of people and greater volume of commerce between nations, and the number of Americans going abroad each year for business and pleasure is increasing at a fantastic rate. This growing interchange among nations requires the services of skilled persons in all walks of life, but they must be persons who have the capability to move and work effectively between our culture and others. The demand is heavy for persons who are well qualified in a particular profession or discipline and who also have language and cultural background in other parts of the world.

The degree of Master of Technology in International Development is offered for the purpose of training students with the above background and interest.

The degree of Master of Technology in International Development is designed to give an international orientation and perspective to the master's degree that is sought in any of the scientific and professional fields represented at this University. It is designed to provide specialized training for students who are interested in utilizing their skills in international activities, whether technical, consultative or administrative in character. It is also available to foreign students who are training for leadership roles in their own country.

Advanced courses and departmental facilities which are available to any other master's degree program at the University are also available to this program to satisfy the needs in the area of the major.

A wide selection of courses is available relating to the developmental, cultural and political aspects of Europe, Latin America and Asia. A number of seminars in different schools relating to international development are conducted each year and they are available to this program.

The modern language department has one of the most complete language laboratories in the area and can use all phases of audio-aural visual instruction in developing language competence. Complete programs are available in Spanish, French and German and some courses are available in Russian and Italian. Instruction in English for foreign students is offered during the academic year and a special Institute for Foreign Students is held each summer.

There are several overseas University projects in agriculture and engineering which afford opportunity for faculty members and graduate students to gain intimate contact with other parts of the world. These include activities in Latin America and the Near East South Asia.

Application for admission to the Graduate School to pursue studies leading to the Master of Technology in International Development is processed through the office of the Graduate Dean and the respective department in which the major course work will be taken.

Requirements for admission are the same as for the Master of Science degree; namely, the applicant must have a bachelor's degree from a college or university that is recognized as standard by a regional or general accrediting agency, and he must have at least a "B" grade average in his undergraduate major.

The program of work for this degree includes the following:

1. A total of 36 semester credits is required, not less than half of which must be in the field of the undergraduate major or closely related areas. The remainder stresses course work providing special orientation and training that prepares the student for accepting technical, consulting, or administrative responsibilities. In the area of the minor, 12 semester credits may be drawn from courses at the 300 and 400 levels, of which no more than six credits may be taken from the 300 level.

2. A summer field experience of 12 weeks in a foreign country, or for the foreign students, equivalent field experience in this country that is closely related to his major (no formal credit allowed toward the degree).

3. A report on the field experience will replace the research thesis requirement of the Master of Science degree.

4. Intensive training in one language (no formal credit allowed toward the degree).

In all other respects the requirements are the same as for the Master of Science degree. For further information contact the Office of International Programs, 209 Daniels Hall.

Landscape Architecture

GRADUATE FACULTY

Professor RICHARD R. WILKINSON, *Head*
Professors: JOSEPH H. COX, HENRY L. KAMPHOEFNER, DUNCAN R. STUART, EDWIN G. TIBURLOW; *Associate Professor:* DONALD H. ENSIGN

The program leading to the Master of Landscape Architecture degree is designed to provide an opportunity for students to engage in exploratory and developmental work in the solution of complex problems. In the practical sense it provides a structure for students to explore the complexity of changing environmental situations and develop more comprehensive techniques in analysis and synthesis. The program requires four semesters of academic work built around a core of four workshops comprising 18 semester hours. As a means to focus workshop activity on a common matrix, an area of North Carolina with complex environmental problems will serve as a laboratory. Each student will be expected to develop his own bias and create programs for its effectiveness in concert with other similarly engaged students. The laboratory area comprises a complex of public and private activity in an embryonic development stage and affords an opportunity to both observe and engage in the process of physical change.

In conjunction with the workshop core, a series of professional electives are required to study the existing methods and techniques of environmental design. These courses entail 12 semester hours and function to integrate the many unrelated approaches to environmental manipulation and design.

The third phase comprises 18 semester hours of student electives in the basic sciences that support effective employment of each student's program. These courses may be elected in any of three universities in the Triangle area: NCSU, Duke or UNC. The purpose of the elective path is to ensure an opportunity for the student to gain a structured insight to another discipline and be conversant with its methodology and content.

The degree requirement, in addition to the 48 hours of academic work, is a seminar delivered in the terminal semester that relates the methods of environmental design to his elective path. Constraints posed by the program are the requirement that the student develop his worked examples within the laboratory area and that he focus both his design skills and supporting knowledge on the final worked example.

Students will be admitted to the program from a variety of disciplines to ensure an adequate mixture of student involvements. The program, however, is based on the student fostering his own view of environmental quality and his work to achieve more comprehensive solutions to ongoing problems of physical change.

DESIGN CORE

A series of workshops treating the region as a group of related systems make up the design core. The sequence of problems begins with simple congruencies and evolves to a complete synthesis of environmental systems in the terminal case study. Courses included in this section are LAR 503, LAR 504, LAR 603 and LAR 604.

ANALYTICAL AND INTEGRATIVE CORE

The analytical and integrative core is a series of courses relating regional landscape design to other design professions and the information sources supporting large-scale design activities.

The courses, LAR 521 and LAR 611, represent a commitment on the part of the landscape architecture faculty to the environmental design and planning disciplines in general. The integrative core courses are not specifically required of the LAR graduate student but can be elected with consent of his adviser as part of the 12 hours required for this phase of the program. Other courses presently existing within established programs at the Raleigh and Chapel Hill campuses can be elected to meet the student's particular needs.

MINOR PROGRAMS

The minor programs are a series of electives in areas of study providing a critical information source. Students will elect courses in these areas under the direction of their minor adviser. Counseling in these areas will be conducted by the associated faculty, and students will be expected to demonstrate a level of proficiency comparable to others developing academic minors in these areas.

FOR ADVANCED UNDERGRADUATES

LAR 400 INTERMEDIATE LANDSCAPE ARCHITECTURE DESIGN (SERIES) 4(1-9) FS
Prerequisite: DN 202 or equivalent or consent of department

The LAR 400 Series is intended to permit students flexibility in scheduling. The courses will cover small scale design, urban landscape architecture, public and institutional design. Each course will be conducted as a workshop/studio to study the problems of project organization, design and execution.

LAR 411, 412 LANDSCAPE TECHNOLOGY 3(1-6) FS
Prerequisite: Junior standing

Techniques and procedures of construction drawing. Contracts, specifications and office practice. Consolidation of previous technical course work by case study projects of various scales.

LAR 491 SPECIAL PROJECTS IN LANDSCAPE ARCHITECTURE 2-4 FS
Prerequisites: Senior standing and 3.0 G.P.A.

The course is intended as a special projects framework for advanced under graduates to do research on a tutorial basis. The course may be scheduled two times.

FOR GRADUATES AND ADVANCED UNDERGRADUATES

LAR 501, 502 LANDSCAPE DESIGN I, II 6(3-9) FS
Prerequisite: Graduate standing

Regional research and analysis. Social criteria of urban and regional design. Transportation systems, land use determination and the design of large scale environmental complexes. Open to graduate students in related fields. Evaluation of non-majors based on contribution of their discipline to group effort.

LAR 503 REGIONAL DESIGN WORKSHOP I 3(0-9) FS
Prerequisite: Graduate standing

Study of current literature in regional design and planning with emphasis on extracting a number of premises, theoretical structures and information handling techniques as a basis for seminar discussions and activities.

LAR 504 REGIONAL DESIGN WORKSHOP II 3(0-9) FS
Prerequisite: Graduate standing

Case study projects designed to explore the relationship between the resource base and the development intentions with the purpose of evolving clear statements of problems involved and their susceptibility to solution problem situations will be developed from differing viewpoints and levels of complexity.

LAR 512 PHYSICAL SYSTEMS 3(2-2) S
Prerequisite: Graduate standing and consent of instructor

Analysis of physical systems and methods of determining relationships between systems with particular reference to natural systems, managed resource systems, development systems and their relationship to development objectives.

LAR 521 INTRODUCTION TO REGIONAL DESIGN 3(2-2) F
Prerequisite: Graduate standing and consent of instructor

A perspective of the measures man has taken to ensure his relation to the general environment. Ecologic determinism, economic and political functionalism and aesthetic movements will be developed in an historical context.

LAR 591, 592 SPECIAL PROJECTS 4(2-6) FS
Prerequisite: Graduate standing

Student evolved projects with emphasis on utilization and expansion of technical processes and techniques to reinforce design solutions. Introduction and investigation of experimental methology. Development of student-evolved interest in specific areas. Open to graduate students in related fields. Evaluation of nonmajors based on contribution of their discipline to group effort.

FOR GRADUATES ONLY

LAR 603 REGIONAL DESIGN III 3(0-9) F
Prerequisites: LAR 503, LAR 504

Course will be directed at a synthesis of information handling methods and environmental design theory within an institutional context. The procedure will be to clarify environmental problems, generate alternative solutions to problems, illustrate the physical implications of alternatives, and evaluate the alternative on the basis of their capacity to be implemented through established institutions and agencies. The course will be structured around existing situations which have the capacity to be abstracted into prototypical situations.

LAR 604 REGIONAL DESIGN IV 3-6 S
Prerequisites: LAR 503, LAR 504, LAR 603

Terminal project for regional design degree students. Projects will be selected and developed by individual students under the direction of his major and minor professors.

LAR 611 PHYSICAL DESIGN POLICY 3(2-2) FS
Prerequisite: LAR 503 and consent of instructor

Course will be directed at a detailed examination of public policy regarding control of the physical environment. Emphasis will be focused on policies

which are directed at control of land use, such as road, utilities, water, etc. and their relationship to policies regarding less tangible commodities such as public health, education, recreation, etc.

LAR 691 DEGREE SEMINAR 0
Prerequisites: LAR 503, LAR 504, LAR 603
Co requisite: LAR 604

Each student in his terminal semester and in conjunction with his terminal case study will prepare and submit to his committee a presentation on the relevance of his minor to the design process with particular reference to his case study.

Marine Sciences

GRADUATE FACULTY

Associate Professor LEONARD J. LANGFELDER, *Chairman*
Professors: MICHAEL AMEIN, ARTHUR W. COOPER, JOHN A. EDWARDS, WILLIAM W. HASSLER, JOHN E. HOBBIE, CARLTON J. LEITH, IAN S. LONGMUIR, JOHN LYMAN, WALTER J. SAUCIER, JAMES C. WILLIAMS, III; *Associate Professors:* BILLY J. COPELAND, LARRY H. ROYSTER, NEIL B. WEBB, CHARLES W. WELBY; *Adjunct Associate Professor:* JAMES R. SMITH; *Assistant Professors:* NORDEN E. HUANG, CHARLES E. KNOWLES, JERRY L. MACHEMEHL

The oceans are perhaps man's last great frontier on earth. Recent developments have made clear how little man really knows of this vast environment and its resources. Further understanding of the oceans and effective utilization of their resources depends upon a thorough knowledge of the geography of the sea and its logistics, the mineral resources of the sea and their extraction, the biological resources of the sea and their utilization, ocean pollution, and deep sea and coastal engineering. North Carolina is richly endowed with marine environments and resources. The state has over 300 miles of shoreline which enclose about 2,500 square miles of shallow sounds and associated habitats. In addition, an extensive continental shelf and proximity to the Gulf Stream and cold northern waters make for rich and varied opportunities for the study of marine science.

Marine Sciences embraces studies in "oceanography," "marine science" and other environmental sciences related to the ocean. The curriculum in marine sci ences brings together the faculties and facilities of both the University of North Carolina at Chapel Hill and North Carolina State University to offer broad graduate training in the various areas of marine sciences. The program gives students a wide choice of faculty advisers, marine science courses and potential research projects. Departments on the North Carolina State campus involved in this curriculum include biochemistry, biological and agricultural engineering, botany, chemical engineering, chemistry, civil engineering, economics, engineering me chanics, food science, genetics, geosciences, mechanical and aerospace engineering, microbiology, physics, soil science and zoology. Teaching and research may take place within the following academic departments of the University of North Carolina at Chapel Hill: bacteriology, biochemistry, botany, chemistry, environmental sciences and engineering, geology, physics and zoology. Course offerings on the Raleigh campus are supplemented by courses at Chapel Hill and Duke University with which reciprocal tuition arrangements can be made.

A variety of facilities are available to students wishing to do research in marine sciences. North Carolina State University has the Pamlico Marine Laboratory at

Aurora and another lab at Hatteras administered by the Department of Zoology. The Harbor Island Marine Science Center at Wrightsville Beach is available for use as a field research station. Students may also use the facilities of the Institute of Marine Science of the University of North Carolina at Chapel Hill and the Bureau of Commercial Fisheries Lab at Beaufort. In addition, individuals with special interests in coastal engineering and protection, coastal geology and coastal ecology may participate in the research of members of the North Carolina Coastal Research Program.

For admission to the curriculum in marine sciences, an undergraduate degree is required in a basic science such as physics, chemistry, biology, bacteriology, botany, zoology, geology or engineering. Undergraduate students who are interested in a graduate program in marine sciences are encouraged to complete the necessary prerequisites for the marine sciences core courses prior to entrance in graduate school.

DEGREE REQUIREMENTS

A graduate student may choose to major in marine sciences or he may major in a field represented by a regular department and minor in marine sciences.

Master of Science—The Master of Science degree program normally will require only three of the five core courses and one semester of Seminar in Marine Sciences. A period of residence at a marine station or on an oceanographic cruise in a program approved by the student's supervisory committee will normally be required. Requirements for the minor, the thesis, the language, admission to candidacy, residence, and final examinations are specified in the regulations of the Graduate School. Arrangements for structuring supervisory committees will be similar to those for the Ph.D. degree.

Doctor of Philosophy—The Ph.D. program for a student will be supervised by a faculty supervisory committee drawn from the graduate faculties of one or both campuses. The supervisory committee will include at least one member of the marine sciences faculty. The requirements for the major for the Ph.D. degree are determined by the student's supervisory committee and normally will include four of the five core courses listed below or substitutions for these courses acceptable as equivalent by his supervisory committee and the marine sciences faculty. The core courses are MAS 487, MAS 529, MAS 584, UNC-CH MAS 101, UNC-CH MAS 105. In addition, a doctoral candidate will normally take the Marine Sciences Seminar at least twice during his period of study and will study or do research at a marine station or on an oceanographic cruise in a program approved by his supervisory committee. Requirements for the minor, the dissertation, the languages, comprehensive examinations, admission to candidacy, residence, and final examinations are specified in the regulations of the Graduate School.

Master of Science minor—Requirements are similar to the Ph.D. minor except that only two of the five core courses and only one additional course, outside the area of the major field, from the list of approved courses normally will be required. Again, final decision on the program of study rests with the supervisory committee.

Doctor of Philosophy minor—For a marine sciences minor in conjunction with a doctoral program, three of the five core courses and at least one semester of seminar normally will be taken. The remaining courses in the minor will come from the list of approved courses outside the major field. Final decision on the program of study rests with the supervisory committee.

Communications concerning the Marine Science Program should be directed to the Chairman of the Marine Science Faculty, in care of the Graduate School, North Carolina State University, or directly to a participating department.

MAS 471 (MAE 471) UNDERSEA VEHICLE DESIGN 3(3 0) S
(See mechanical and aerospace engineering, page 223.)

MAS 487 (CE 487, OY 487) PHYSICAL OCEANOGRAPHY 3(3 0) S
(See physical oceanography, page 248.)

MAS 529 (ZO 529) BIOLOGICAL OCEANOGRAPHY 3(3 0) S
(See zoology, page 334.)

MAS 541 (OY 541, CE 541) GRAVITY WAVE THEORY I 3(3-0) S
(See physical oceanography, page 249.)

MAS 551 (OY 551) OCEAN CIRCULATION 3(3-0) S
(See physical oceanography, page 249.

MAS 581 (CE 581) INTRODUCTION TO OCEANOGRAPHIC ENGINEERING 3(3 0) F
(See civil engineering, page 104.)

MAS 584 (GY 584) MARINE GEOLOGY 3(3-0) S
(See geology, page 171.)

MAS 591, 592 MARINE SCIENCES SEMINAR 1(1 0) S

A seminar designed to give perspective in the field of marine science. Topics vary from semester to semester. In order to obtain credit a student must deliver a seminar.

MAS 601, 602 (OY 601, 602) ADVANCED PHYSICAL OCEANOGRAPHY I, II 3(3 0) FS
(See physical oceanography, page 249.)

MAS 605, 606 (OY 605, 606; EM 605, 606) ADVANCED GEOPHYSICAL FLUID MECHANICS I, II 3(3-0) FS
(See physical oceanography, page 249.)

MAS 613, 614 (OY 613, 614; EM 613, 614) PERTURBATION METHOD IN FLUID MECHANICS I, II 3(3-0) FS
(See physical oceanography, page 249.)

MAS 693 SPECIAL TOPICS IN MARINE SCIENCES 1 3
Prerequisites: Graduate standing and consent of staff

This course will provide the opportunity for advanced graduate students to study in special problem areas in marine sciences. Various areas in the program may use this course concurrently in their areas.

UNC-CH MAS 101 GENERAL OCEANOGRAPHY 3(3-0) F

A study of the seas and their processes.

UNC CH MAS 105 (ESE 128) CHEMICAL OCEANOGRAPHY 3(3-0) S

A variation and abundance of sea water constituents. The chemical, physical and biological processes contributing to the distribution and problems of dispersion of conservative and nonconservative substances are considered.

Messrs. Lyman, Kuenzler and Johnson

RECOMMENDED COURSES IN PARTICIPATING DEPARTMENTS

Biological Marine Science

BO 360 (ZO 360) INTRODUCTION TO ECOLOGY
BO 560 (ZO 560) PRINCIPLES OF ECOLOGY

BO 574 (MB 574) PHYCOLOGY
MB 401, 402 GENERAL MICROBIOLOGY
ZO 420 FISHERY SCIENCE
ZO 441 ICHTHYOLOGY
ZO 515 GROWTH AND REPRODUCTION OF FISHES
ZO 517 POPULATION ECOLOGY
ZO 519 LIMNOLOGY
ZO 619 ADVANCED LIMNOLOGY
ZO 621 FISHERY SCIENCE

Geological Marine Science

GY 452 EXOGENIC MATERIALS AND PROCESSES
GY 552 EXPLORATORY GEOPHYSICS
GY 563 APPLIED SEDIMENTOLOGY
GY 567 GEOCHEMISTRY
SSC 553 SOIL MINERALOGY

Physical Marine Science

CE 517 WATER TRANSPORTATION
CE 548, 549 ENGINEERING PROPERTIES OF SOILS I, II
CE 641, 642 ADVANCED SOIL MECHANICS
EM 504 MECHANICS OF IDEAL FLUIDS
EM 505 MECHANICS OF VISCOUS FLUIDS I
EM 612 MECHANICS OF VISCOUS FLUIDS II
MAE 651 PRINCIPLES OF FLUID MOTION

Materials Engineering

GRADUATE FACULTY

Professor WILLIAM W. AUSTIN, *Head*
Professors: JOE R. BEELER, JR., ABDEL A. FAHMY, JAMES K. MAGOR, KHOSROW L. MOAZED; *Research Professors:* HAYNE PALMOUR, III, HANS H. STADELMAIER, ROBERT F. STOOPS; *Professor Emeritus:* WILLIAM W. KRIEGEL; *Adjunct Professor:* HENRY M. DAVIS; *Associate Professors:* RAY B. BENSON, JR., JOHN V. HAMME, GEORGE O. HARRELL, CHARLES R. MANNING, JR.; *Adjunct Associate Professor:* GEORGE MAYER; *Assistant Professor:* JOHN C. HURT

The Department of Materials Engineering offers graduate programs leading to the degrees of Master of Science and Doctor of Philosophy. Graduate courses in materials science and engineering are also offered for the benefit of students majoring in other areas who may be interested in pursuing advanced work in the materials fields.

Financial assistance is available to qualified graduate students in the Department of Materials Engineering. Graduate assistantships permit half-time studies toward advanced degrees, and half time to be devoted to teaching or research. Also, sponsored fellowships and traineeships that permit full-time graduate study are available on a competitive basis. Applications should be made to the department.

During the past decade rapid developments in aerospace, electronics and nuclear technologies, and their attendant materials problems have resulted in

increased emphasis on graduate study and research on the fundamental properties and behavior of materials. At present, intensifying demands of the so called societal problem (housing, pollution, communications, health and medicine, and the like), are bringing about dramatic shifts in research emphases in the direc tion of applications-oriented research. Much of this work is aimed at optimum solutions to these crisis problems. Opportunities for men and women with graduate training in these areas are developing, and in the decade of the seventies this work will of necessity become the dominant role of science, engineering and technology.

The highly flexible graduate programs offered by the Department of Materials Engineering are particularly well suited to the development of trained leaders to fill these opportunities in the materials disciplines. The very diversity of under-graduate curricula in engineering and physical sciences, and the spread of subject matter that falls within the materials field, mitigate against the adoption of a rigidly formalized sequence of courses to be taken by all candidates for advanced degrees in materials. Flexibility in the selection of the graduate student's pro-gram in materials regardless of his prior technical training—whether in ceramic, chemical, civil, electrical, mechanical, metallurgical or nuclear engineering, or in the physical sciences is recognized by the Department of Materials Engineering to be of the utmost importance. In this program emphasis may be placed upon fundamental research or upon the application of basic concepts in materials science to various engineering and societal problems.

Therefore, the programs of study for graduate students majoring in materials will be determined by the candidate in consultation with his adviser and graduate committee, and will depend on the background and the needs of the candidate. The needs of graduate students majoring in fields other than materials, yet seek ing a minor in this latter discipline may also be satisfied from the courses of instruction offered by the Department of Materials Engineering.

Although the designation, Department of Materials Engineering, was adopted in 1969, the major components of this department namely, ceramic engineering and metallurgical engineering, have had a much longer tradition at this University. In particular the faculty in ceramic engineering has been actively engaged in post graduate teaching and research for more than three decades, and since 1950 this University has been the only institution in the Southeast which has offered the doctorate in ceramic engineering. In addition to this, a cooperative arrangement with the Department of Chemical Engineering has been established under which graduate study and research in polymeric materials are available.

In addition to the advanced work in materials science and engineering, the School of Engineering also offers an excellent program of supporting courses in all of the degree granting departments within the School. Equally strong supporting programs of instruction are also offered in a number of other schools within the University.

FOR ADVANCED UNDERGRADUATES

MAT 401 MATERIALS PROCESSING 3(3-0)
Prerequisites: MAT 301, MAT 450, MAT 412

Techniques for the processing of ceramic, metallic and polymeric materials to control properties, form and appearance through considerations of thermal, chemical, mechanical, electrical, magnetic and nuclear energy. Both traditional and exotic processes are covered utilizing fundamental materials science and engineering science principles.

MAT 411, 412 PHYSICAL PRINCIPLES IN MATERIALS SCIENCE I, II 3(3-0)
Prerequisites: (411) MAT 201; (412) MAT 411

Introduction to the fundamental physical concepts of ceramic, metallic and polymeric materials. Relation between properties and structure.

MAT 417 CERAMIC SUBSYSTEM DESIGN 3(2-3)
Prerequisite: MAT 312

Individual and team study involving the interdependence of plant layout, processes, equipment and materials in the economic design of engineering systems and subsystems. Discussion of design principles, sources of data, creativity and economic analysis to encourage original solutions to problems of current and future need and interest in the ceramic profession.

MAT 423, 424 MATERIALS FACTORS IN DESIGN I, II (423) 3(3-0)
Prerequisites: (423) MAT 450; (424) MAT 423 (424) 4(3 3)
Corequisites: (423) MAT 431; 424) MAT 432

Selection of materials for specific engineering applications. Manufacturing processes and their relation to product use.

MAT 431, 432 PHYSICAL METALLURGY I, II 3(3-0)
Prerequisites: (431) MAT 412; (432) MAT 431

Alloy design; control of properties through microstructures; principles of heat treatment; strengthening mechanisms.

MAT 435, 436 PHYSICAL CERAMICS I, II (435) 4(3-3)
Prerequisites: (435) MAT 412; (436) 435 (436) 3(2 3)

A project-oriented course in which starting materials of various types of ceramic products are characterized including analysis of reactions, selection of processing parameters, processing, measurement of properties appropriate to the ceramic analysis, and correlation of all materials and processing parameters with properties and microstructures. Projects are selected to exemplify characteristic types of ceramics.

MAT 437 INTRODUCTION TO THE VITREOUS STATE 3(3 0)
Prerequisite: MAT 301

An introductory study of the vitreous state to include the structure, properties and type of glasses (including glazes and enamels). Opacity color and devitrification. Nature of the glassy phase in kiln fired ceramics.

MAT 450 MECHANICAL PROPERTIES OF MATERIALS 3(2-3)
Prerequisite: MAT 201

Elastic, plastic and fracture phenomena in solids including yielding, strain hardening, brittle fracture, creep and fatigue.

MAT 451 PRINCIPLES OF CERAMIC ENGINEERING 3(3 0) F
Prerequisite: CH 433 or MAE 302 or CHE 315

An advanced treatment of fundamental relationships among ceramic materials, processes and properties. Designed to provide an adequate background for students from other engineering and physical science curricula to permit effective study of ceramic engineering at the graduate level.

MAT 491 MATERIALS ENGINEERING SEMINAR 1(1-0)
Prerequisite: Senior standing

Literature survey of selected topics in materials engineering. Oral and written reports and discussions.

MAT 493, 494 CERAMIC FIELD EXERCISES I, II 1(0-3)
Prerequisite: Senior standing

Selected plant visitations, lectures by practicing ceramic engineers, reports on industrial organizations engaged in manufacture or use of ceramics. Discussions of professional organizations and professional ethics.

MAT 495, 496 EXPERIMENTAL ENGINEERING I, II 3(1 6)
Prerequisite: Senior standing

Advanced engineering principles applied to a specific project dealing with metallurgy, materials or general experimental work. A seminar period is provided and a written report required.

FOR GRADUATES AND ADVANCED UNDERGRADUATES

MAT 500 MODERN CONCEPTS IN MATERIALS SCIENCE 3(3-0) F
Prerequisite: MAT 412

Applications of current theories of materials such as crystal theory, continuum and quasi-continuum theories, phenomenological theories, etc., to the solution of materials problems.

MAT 503 CERAMIC MICROSCOPY 3(2 3) F
Prerequisite: GY 331

Transmitted and reflected light techniques for the systematic study of ceramic materials and products.

MAT 509 HIGH VACUUM TECHNOLOGY 3(2-3) Sum.
Prerequisite: CH 433 or MAE 301

Properties of low-pressure gases and vapors. Production, maintenance and measurement of high vacuum; design, construction and operation of high vacuum, high temperature facilities. Properties and reactions of materials which are processed, tested and/or utilized in high vacuum environments.

MAT 510 STRUCTURE OF CRYSTALLINE MATERIALS 3(3 0) F
Prerequisite: MAT 411
Corequisite: MAT 500

The lattice structure of crystals, including group theory applications, reciprocal lattice concept and the study of crystal structure as related to bonding.

MAT 520 THEORY AND STRUCTURE OF MATERIALS 3(3-0) F
Prerequisite: MAT 510

Structure of liquids, and crystalline and amorphous solids used in engineering systems. Crystallinity and thermal properties. Ionic crystals in ceramic systems. The metallic state and alloy behavior. Emphasis is placed on the relation between fundamental materials parameters and engineering properties.

MAT 527 REFRACTORIES IN SERVICE 3(3-0) S
Prerequisite: MAT 411

A study of the physical and chemical properties of the more important refractories in respect to their environment in industrial and laboratory furnaces.

MAT 529 PROPERTIES OF HIGH TEMPERATURE MATERIALS 3(3-0) S
Prerequisite: MAT 201

Effects of temperature on the physical, mechanical and chemical properties of inorganic materials; relationships between microstructure and high temperature properties; applications of ceramics, metals and composites at elevated temperatures.

MAT 530 PHASE TRANSFORMATION IN MATERIALS I 3(3-0) F
Corequisite: MAT 500

Kinetic theory of transformations, nucleation theory, homogeneous and heterogeneous nucleation, growth of crystals, epitaxial thin films.

MAT 533, 534 ADVANCED CERAMIC ENGINEERING DESIGN I, II 3(2 3) FS
Prerequisite: MAT 417

Advanced studies in analysis and design of ceramic products, processes and systems leading to original solutions of current industrial problems and the development of new concepts of manufacturing.

MAT 540 GLASS TECHNOLOGY 3(3-0) F
Prerequisite: MAT 437

Fundamentals of glass manufacture including compositions, properties and application of the principal types of commercial glasses.

MAT 541, 542 PRINCIPLES OF CORROSION I, II 3(2-3) FS
Prerequisite: MAT 431 or CH 431

The fundamentals of metallic corrosion and passivity. The electro-chemical nature of corrosive attack, basic forms of corrosion, corrosion rate factors, methods of corrosion protection. Laboratory work included.

MAT 550 DISLOCATION THEORY 3(3-0) F
Prerequisite: MAT 450

Structure, energetics, stress and strain fields, interactions and motion of dislocations in solids.

MAT 556 COMPOSITE MATERIALS 3(3-0) F
Prerequisite: MAT 450

Basic principles underlying the properties of composite materials as related to properties of the individual constituents and their interaction. Emphasis is placed on the design of composite systems to yield desired combinations of properties.

MAT 562 (NE 562) MATERIALS PROBLEMS IN NUCLEAR ENGINEERING 3(3-0) S
Prerequisite: PY 410 or consent of instructor

Reactor component design considerations determined by materials properties as well as by nuclear function are covered. Emphasis is placed on radiation effects and other concepts pertinent to the selection of materials for nuclear reactors for either terrestrial or space applications.

MAT 573 (NE 573) COMPUTER EXPERIMENTS IN MATERIALS ENGINEERING 3(3-0) F
Prerequisites: PY 407, MA 301

The basic techniques for constructing both statistical (Monte Carlo) and deterministic computer experiments will be explained and discussed from the standpoint of immediate use in the solution of current engineering research and development problems.

MAT 595, 596 ADVANCED MATERIALS EXPERIMENTS I, II 3(1-6) FS
Prerequisite: MAT 411

Advanced engineering principles applied to a specific experimental project dealing with materials. A seminar period is provided and a written report is required.

FOR GRADUATES ONLY

MAT 601 CERAMIC PHASE RELATIONSHIPS 3(3-0) S
Prerequisite: Consent of instructor

Heterogeneous equilibrium, phase transformations, dissociation, fusion, lattice energy, defect structure, thermodynamic properties of ionic phases and silicate melts.

MAT 603 ADVANCED CERAMIC REACTION KINETICS 3(3-0) S
Prerequisite: MAT 510

Fundamental study of the kinetics of high temperature ceramic reactions such as diffusion, nucleation, grain growth, recrystallization, phase transformation, vitrification and sintering.

MAT 610 X-RAY DIFFRACTION 3(3-0)F
Prerequisite: MAT 510

The properties and scattering behavior of X-rays by electrons, ions and atoms. Theory and applications of X-ray diffraction techniques such as Laue back reflection, the rotating crystal and powder methods, texture studies and residual stress analysis.

MAT 615 ELECTRON MICROSCOPY 3(3-0) F
Prerequisites: MAT 550, MAT 610

Theory of imaging and diffraction of electrons. Analysis of structures using electron microscopy.

MAT 621 THEORY AND STRUCTURE OF AMORPHOUS MATERIALS 3(3-0) S
Prerequisite: MAT 520

Bond types and structure of amorphous solids, relations of bond types and structure to flow mechanisms, electrical, optical and thermal properties.

MAT 622 THEORY AND STRUCTURE OF CERAMIC MATERIALS 3(3-0) F
Prerequisite: MAT 520

Electrical and optical properties of non-conducting materials, ferro-electric behavior and materials parameters, magnetic properties of non-metallics, semi-conducting materials.

MAT 623 THEORY AND STRUCTURE OF METALLIC MATERIALS 3(3 0) F
Prerequisite: MAT 520

The metallic state, its atomic and electronic structure. Electron theory of metals and alloys. Advanced methods of determining electronic structure in metallic materials.

MAT 630 PHASE TRANSFORMATION IN MATERIALS II 3(3 0) F
Prerequisites: MAT 510, MAT 530, MAT 550

Formal theories of solid-solid transformations, transformation mechanisms, transformation morphologies.

MAT 631, 632 ADVANCED PHYSICAL CERAMICS I, II 3(2 3) FS
Corequisites: MAT 510, 610 or MAT 530, 630 or EM 501, 502 or PY 503, 552

Lattice structures and lattice energies in crystalline ceramics; relationships with elastic, optical and thermal properties. Effects of constitution and micro-structure on lattice-sensitive properties. The defect crystalline state in ceramics;

vacancies, color centers, dislocations, boundaries. Crystal growth. Plastic deformation processes, including creep and fatigue; the ductile-brittle transition. Structure sensitive properties of crystalline, vitreous and composite ceramics; effects of constitution, microstructure and nonstoichiometry.

MAT 633 ADVANCED MECHANICAL PROPERTIES OF MATERIALS 3(3 0) F
Prerequisite: MAT 630

The theories of yield strength, work hardening, creep, fracture, and fatigue of crystalline materials will be developed in terms of dislocation theory.

MAT 661 DIFFRACTION THEORY 3(3-0) F
Prerequisite: MAT 610

The diffraction of light, X rays, electrons and neutrons by matter is represented in Fourier space, and the known methods of generating the Fourier transform (usually atomic structure) are reviewed. Exploration by high and low angle scattering techniques of crystals, paracrystals, liquids, polydispersed aggregates, and fibers is treated. The feasibility of direct analysis by convolution integrals is studied.

MAT 691, 692 SPECIAL TOPICS IN MATERIALS ENGINEERING 3(3-0) FS
Prerequisite: Graduate standing

Special studies of advanced topics in materials engineering.

MAT 695 MATERIALS ENGINEERING SEMINAR 1(1-0) FS

Reports and discussion of special topics in materials engineering and allied fields.

MAT 699 MATERIALS ENGINEERING RESEARCH Credits Arranged

Independent investigation of an appropriate research problem. A report on this investigation is required as a graduate thesis.

Mathematics

GRADUATE FACULTY

Professor NICHOLAS J. ROSE, *Head*

Professors: JOHN W. BISHIR, ROBERTS C. BULLOCK, JOHN M. A. DANBY, WALTER J. HARRINGTON, KWANGIL KOH, JACK LEVINE, PAUL E. LEWIS, JIANG LUH, HOWARD M. NAHIKIAN, *Graduate Administrator,* PAUL A. NICKEL, HUBERT V. PARK, HANS SAGAN, HERBERT E. SPEECE, RAIMOND A. STRUBLE, HUBERTUS R. VAN DER VAART, OSCAR WESLER, LOWELL S. WINTON; *Adjunct Professor:* IAN N. SNEDDON; *Visiting Professor:* MAKOTO ITOH; *Associate Professors:* ERNEST E. BURNISTON, RICHARD E. CHANDLER, WILLIAM G. DOTSON, JR., RONALD O. FULP, JOHN R. KOLB, JOE A. MARLIN, JOHN W. QUERRY, JAMES B. WILSON; *Assistant Professors:* HARVEY J. CHARLTON, DENNIS E. GAROUTTE, RALPH GELLAR, DONALD J. HANSEN, ROBERT E. HARTWIG, JAMES E. HUNEYCUTT, JR., ROBERT H. MARTIN, JR., CARL D. MEYER, LAVON B. PAGE, CHIA-VEN PAO, ROBERT T. RAMSAY, ROBERT SILBER, JASON L. SOX JR., ERNEST L. STITZINGER, DAVID F. ULLRICH, WILLIAM M. WATERS, JR.

The Department of Mathematics offers programs in both mathematics and applied mathematics leading to the degrees of Master of Science, Master of Mathematics, Master of Applied Mathematics and Doctor of Philosophy.

There is a consistent demand for persons with graduate training in mathematics and its applications. Employment opportunities are available in colleges and universities, industry and government.

The philosophy of the department is to maintain within its faculty, and in its research and course offerings, a sound balance between the "pure" and "applied" aspects of mathematics. We believe that the study of abstract systems can help in the solution of concrete problems and that the study of specific problems often stimulates the growth and creation of new mathematics. Thus a student will find in this department no artificial separation between pure and applied mathematics and, in fact, he is encouraged to incorporate both aspects in his course of study.

Applicants for admission should have an undergraduate degree in mathematics or its equivalent. This should include a year of mathematical analysis (or advanced calculus) and a year of modern algebra, including linear algebra. All applicants are required to take the Graduate Record Examination including the Advanced Test in Mathematics.

A number of research and teaching assistantships are available. A student holding a half-time assistantship is allowed to carry a course load of nine semester hours. A limited number of NSF, NASA, NDEA and Ford Fellowships are also available.

The requirements for the master's degree include 30-33 semester hours of approved course credits and a comprehensive examination. A thesis is required for the Master of Science degree. Foreign languages are not required for the master's degrees.

There is no prescribed minimum number of courses for the degree of Doctor of Philosophy. Normally a student will take approximately 60 semester hours of course credits including certain core courses in algebra, analysis, topology and applied mathematics. Independent reading and participation in seminars constitute an indispensable part of the doctoral program.

All doctoral students are required to have a reading knowledge of two modern foreign languages or a knowledge in depth of one. Comprehensive examinations are also required. These consist of a written examination designed to test basic knowledge of algebra, analysis, and topology and an oral examination on material related to the field of proposed thesis work.

The heart of the doctoral program is the dissertation. It must be original research resulting in a significant contribution in some area of mathematics or its applications and should be worthy of publication in the current literature. The doctoral dissertation must be defended at the final oral examination.

A detailed statement of requirements for graduate degrees is available on request from the departmental office.

FOR ADVANCED UNDERGRADUATES

MA 401 APPLIED DIFFERENTIAL EQUATIONS II 3(3-0) FS
Prerequisite: MA 301 or MA 312

The wave, heat and Laplace equations. Solutions by separation of variables and expansion in Fourier Series or other appropriate orthogonal sets.

MA 403 INTRODUCTION TO MODERN ALGEBRA 3(3-0) FS
Prerequisite: One year of calculus

Sets and mappings; equivalence relations; groups, homomorphisms, cosets, Cayley's theorem, symmetric groups, quotient groups; rings; integral domains; Euclidean algorithm; polynomial rings, ideals, quotient rings.

MA 404 FUNDAMENTAL CONCEPTS OF GEOMETRY 3(3-0) S
Prerequisite: One year of calculus

Foundations of geometry; laws of logic; affine geometry; geometric transforma tions; homogeneous coordinates; comparison of Euclidean and non-Euclidean geometries.

MA 405 INTRODUCTION TO MATRICES AND LINEAR TRANSFORMATIONS 3(3-0) FS
Prerequisite: One year of calculus

Determinants, linear equations, linear transformations and matrices, operations with matrices, eigenvalues, introduction to bilinear and quadratic forms.

MA 408 ADVANCED GEOMETRY 3(3-0) F
Prerequisite: One year of calculus

Topics from modern geometry; poles and polars; non-Euclidean geometry; analytical geometry from a vector point of view; elementary geometry from an advanced standpoint.

MA 410 THEORY OF NUMBERS 3(3-0) S
Prerequisite: One year of calculus

This course is concerned with the investigation of the arithmetic properties of the integers. Topics include congruences, arithmetic functions, quadratic residues, the quadratic reciprocity law of Gauss, primitive roots, diophantine equations and algebraic number fields.

MA 421 INTRODUCTION TO PROBABILITY 3(3-0) FS
Prerequisite: One year of calculus

Axioms of probability, conditional probability, combinational analysis, random variables, expectation, simple stochastic processes.

MA 425 MATHEMATICAL ANALYSIS I 3(3-0) F
Prerequisite: MA 232

Real number system, functions and limits, topology on the real line, continuity, differential and integral calculus for functions of one variable.

MA 426 MATHEMATICAL ANALYSIS II 3(3-0) S
Prerequisite: MA 425

Infinite series, uniform convergence, calculus of several variables, topology in n dimensions, limits, continuity, differentiability, implicit functions, multiple integrals, line and surface integrals.

MA 430 INTRODUCTION TO APPLIED MATHEMATICS 3(3-0) F
Prerequisites: MA 426, MA 421

Formulation of scientific problems in mathematics terms, interpretation and evaluation of the solutions. Topics discussed will be chosen from problems in managerial, behavior and life sciences as well as the physical sciences.

MA 433 HISTORY OF MATHEMATICS 3(3-0) S
Prerequisite: One year of calculus

Evolution of the number system; trends in the development of modern mathematics; lives and contributions of outstanding mathematicians.

MA 491 READING IN HONORS MATHEMATICS 2-6 FS
Prerequisites: Membership in honors program, consent of department

MA 493 SPECIAL TOPICS 1 6 FS
Prerequisite: Consent of department

FOR GRADUATES AND ADVANCED UNDERGRADUATES

MA 504 (NE 504) MATHEMATICAL METHODS IN ENGINEERING 3(3-0) F
Prerequisite: MA 301 or MA 312

Survey of mathematical methods for engineers. Topics include ordinary differential equations, matrices, partial differential equations, difference equations, numerical methods, elements of statistics. Techniques and applications to engineering are stressed. This course cannot be taken for credit by mathematics majors.

MA 505 (IE 505, OR 505) MATHEMATICAL PROGRAMMING I 3(3-0 F Sum.
(See industrial engineering, page 191.)

MA 511 ADVANCED CALCULUS I 3(3 0) FS
Prerequisite: MA 301

Fundamental theorem on continuous functions; convergence theory of sequences, series and integrals; the Riemann integral.

MA 512 ADVANCED CALCULUS II 3(3-0) FS
Prerequisite: MA 511

General theorems of partial differentiation; implicit function theorems; vector calculus in 3-space; line and surface integrals; classical integral theorems.

MA 513 INTRODUCTION TO COMPLEX VARIABLES 3(3 0) FS
Prerequisite: MA 511 or MA 425

Operations with complex numbers, derivatives, analytic functions, integrals, definitions and properties of elementary functions, multivalued functions, power series, residue theory and applications, conformal mapping.

MA 514 METHODS OF APPLIED MATHEMATICS 3(3 0) S
Prerequisite: MA 511 or MA 426

Introduction to integral equations, the calculus of variations and difference equations.

MA 515 LINEAR FUNCTIONAL ANALYSIS I 3(3-0) F
Prerequisite: MA 426

Metric spaces; Lebesgue measure and integration; L^p and l^p spaces; Riesz Fischer and Riesz representation theorems; normed linear spaces and Hilbert spaces.

MA 516 LINEAR FUNCTIONAL ANALYSIS II 3(3-0) S
Prerequisite: MA 515

Basic theorems in Banach spaces, dual spaces, weak topologies; basic theorems in Hilbert spaces, and detailed theory of linear operators on Hilbert spaces; spectral theorem for self-adjoint completely continuous linear operators.

MA 517 INTRODUCTION TO TOPOLOGY 3(3 0) FS
Prerequisite: MA 426

Sets and functions, metric spaces, topological spaces, compactness, separation, connectedness.

MA 518 CALCULUS ON MANIFOLDS 3(3-0) S
Prerequisite: MA 426

Calculus of several variables from a modern viewpoint. Differential and integral calculus of several variables, vector functions, integration on manifolds, Stoke's and Green's theorems, vector analysis.

MA 520 LINEAR ALGEBRA 3(3-0) FS
Prerequisite: MA 231 or MA 405

Vector spaces, linear mappings and matrices, determinants, inner product spaces, bilinear and quadratic forms, canonical forms, spectral theorem.

MA 521 FUNDAMENTALS OF MODERN ALGEBRA 3(3-0) FS
Prerequisite: MA 403

Groups, normal subgroups, quotient groups, Cayley's theorem, Sylow's theorem. Rings, ideals and quotient rings, polynomial rings. Fields, extension fields, elements of Galois theory.

MA 523 TOPICS IN APPLIED MATHEMATICS 3(3-0) F
Prerequisites: MA 515, MA 520

Formulation of scientific problems in mathematical terms, interpretation and evaluation of the mathematical analysis of the resulting models. The course will discuss problems in behavioral and biological sciences as well as problems in mechanics of discrete and continuous systems. Some discussion of optimization and the calculus of variations.

MA 524 MATHEMATICAL METHODS IN THE PHYSICAL SCIENCES I 3(3-0) F
Prerequisites: MA 405, MA 512

Green's functions and two-point boundary value problems; elementary theory of distributions; generalized Green's functions. Finite and infinite dimensional inner product spaces; Hilbert spaces; completely continuous operators; integral equations; the Fredholm alternative; eigenfunction expansions; applications to potential theory. Nonsingular and singular Sturm-Liouville problems; Weil's theorem.

MA 525 MATHEMATICAL METHODS IN THE PHYSICAL SCIENCES II 3(3-0) S
Prerequisite: MA 524

Distribution theory in n-space; Fourier transforms; partial differential equations, generalized solutions, fundamental solutions, Cauchy problem, wave and heat equations, well-set problems. Laplace's equation, the Dirichlet and Neumann problems, integral equations of potential theory, Green's functions, eigenfunction expansions.

MA 527 (CSC 527) NUMERICAL ANALYSIS I 3(3-0) FS
Prerequisites: CSC 101 or CSC 111, MA 301 or MA 312, MA 231 or MA 405

Theory of interpolation, numerical integration, iterative solutions of nonlinear equations, numerical integration of ordinary differential equations, matrix inversion and solution of simultaneous linear equations.

MA 528 (CSC 528) NUMERICAL ANALYSIS II 3(3-0) FS
Prerequisite: MA 527 (CSC 527)

Least squares data approximation, expansions in terms of orthogonal functions, Gaussian quadrature, economization of series, minimax approximations, Pade approximations, eigenvalues of matrices.

MA 532 THEORY OF ORDINARY DIFFERENTIAL EQUATIONS 3(3 0) S
Prerequisites: MA 301 or MA 312, MA 405, advanced calculus

Existence and uniqueness theorems, systems of linear equations, fundamental matrices, matrix exponential, series solutions, regular singular points; plane autonomous systems, stability theory.

MA 536 LOGIC FOR DIGITAL COMPUTERS 3(3-0) F
Prerequisite: MA 405

Introduction to symbolic logic and Boolean algebra; finite state-valued calculus and its application to combinational networks; sequential finite-state machines and their mathematical formulation; analysis and synthesis problems of sequential machines.

MA 537 MATHEMATICAL THEORY OF DIGITAL COMPUTERS 3(3 0) S
Prerequisite: MA 536

The sequential machine and its characteristic semi-group; micro-programmed computers; general purpose computers and special-purpose computers; Turing machine and infinite-state machines; nondeterministic switching system and probabilistic automata.

MA 541 (ST 541) THEORY OF PROBABILITY I 3(3-0) F
Prerequisite: MA 425 or MA 511

Axioms, combinatorial analysis, conditional probability, independence, random variables, expectation, special discrete and continuous distributions, probability and moment generating functions, central limit theorem, laws of large numbers, branching processes, recurrent events, random walk.

MA 542 (ST 542) THEORY OF PROBABILITY II 3(3-0) S
Prerequisites: MA 405, MA 541

Markov chains and Markov processes, Poisson process, birth and death processes, queuing theory, renewal theory, stationary processes, Brownian motion.

MA 545 SET THEORY AND FOUNDATIONS OF MATHEMATICS 3(3-0) S
Prerequisite: MA 403

Logic and the axiomatic approach, the Zermelo-Fraenkel axioms and other systems, algebra of sets and order relations, equivalents of the Axiom of Choice, one-to-one correspondences, cardinal and ordinal numbers, the Continuum Hypothesis.

MA 555 (PY 555) MATHEMATICAL INTRODUCTION TO CELESTIAL MECHANICS 3(3-0) F
Prerequisite: One year of advanced calculus

Central orbits, N-body problems, 3-body problem, Hamilton-Jacobi theory, Perturbation theory, applications to motion of celestial bodies.

MA 556 (PY 556) ORBITAL MECHANICS 3(3-0) F
Prerequisites: MA 301, MA 405, knowledge of elementary mechanics and computer programming

Keplerian motion, interative solutions, numerical integration, differential corrections and space navigation, elements of probability, least squares, sequential estimation, Kalman filter.

MA 571 (BMA 571, ST 571) BIOMATHEMATICS I 3(3-0) F
(See biomathematics, page 80.)

MA 572 (BMA 572, ST 572) BIOMATHEMATICS II 3(3-0) S
(See biomathematics, page 81.)

MA 581 SPECIAL TOPICS 1-6
Prerequisite: Consent of department

FOR GRADUATES ONLY

MA 600 ADVANCED DIFFERENTIAL EQUATIONS I 3(3-0) F
Prerequisites: MA 513, MA 518, MA 520

Analytical theory of ordinary differential equations, stability theory, perturbations, asymptotic behavior, nonlinear oscillations.

MA 601 ADVANCED DIFFERENTIAL EQUATIONS II 3(3-0) S
Prerequisite: MA 600

Qualitative theory of ordinary differential equations, general properties of dynamical systems, limit sets, integral invariants, global theory.

MA 602 PARTIAL DIFFERENTIAL EQUATIONS I 3(3-0) F
Prerequisites: MA 426, MA 520, MA 532

First order equations, initial value problems; theory of characteristics; existence and uniqueness theorems; hyperbolic equations.

MA 603 PARTIAL DIFFERENTIAL EQUATIONS II 3(3-0) S
Prerequisite: MA 602

Elliptic and parabolic equations; approximation methods; generalized solutions.

MA 604 TOPOLOGY 3(3-0) S
Prerequisites: MA 515, MA 520, MA 521

Topological spaces: separation axioms, compactness, connectedness, local topological properties; continuous mappings, and convergence; product and quotient spaces; compactification; homotopy equivalence of mappings, fundamental groups, covering spaces, universal coverings, deck transformations.

MA 605 HOMOLOGY AND MANIFOLDS 3(3-0) F
Prerequisite: MA 604

Homology; either simplicial or singular theory, excision theorem, homotopy theorem, Mayer-Vietroris theorem and computation of groups, topology and geometry of differentiable manifolds, vector fields, Lie derivations, and differential equations; smooth partitions of unity, integration, differential forms and Stokes theorem; the DeRham cohomology and the DeRham theorem.

MA 606 (ST 606, OR 606) MATHEMATICAL PROGRAMMING II 3(3-0) S
(See statistics, page 302.)

MA 611 ANALYTIC FUNCTION THEORY I 3(3-0) FS
Prerequisite: MA 426

A rigorous introduction to the theory of functions of a complex variable. The complex plane, functions, Möbius transformations, the exponential and logarithmic functions, trigonometric functions, infinite series, integration in the complex plane, Cauchy's theorem and its consequences.

MA 612 ANALYTIC FUNCTION THEORY II 3(3-0) FS
Prerequisite: MA 611

A continuation of MA 611. Taylor and Laurent series, the residue theorem, the argument principle, harmonic functions and the Dirichlet problem, analytic continuation and the monodromy theorem, entire and meromorphic functions, the Weierstrass product representation and the Mittag-Leffler partial fraction representation, special functions, conformal mapping and the Picard theorem.

MA 613 TECHNIQUES OF COMPLEX ANALYSIS 3(3-0) S
Prerequisite: MA 513 or MA 611

A course dealing with the applications of complex analysis to mathematical problems in physical science in the setting of the potential equation and other partial differential equations: contour integrals, special functions of mathematical physics from the line integral point of view, solution of problems in potential theory, asymptotic methods including WKB, and Wiener-Hopf techniques.

MA 615 THEORY OF FUNCTIONS OF A REAL VARIABLE I 3(3-0) F
Prerequisite: MA 517

Real functions, semicontinuity, upper and lower limits, sequences; Lebesgue measure and integration, absolute continuity and differentiation.

MA 617 (ST 617) MEASURE THEORY AND ADVANCED PROBABILITY 3(3-0) F
(See statistics, page 303.)

MA 618 (ST 618) MEASURE THEORY AND ADVANCED PROBABILITY 3(3-0) S
(See statistics, page 303.)

MA 619 (ST 619) TOPICS IN ADVANCED PROBABILITY 3(3-0) Sum.
(See statistics, page 303.)

MA 620 MODERN ALGEBRA I 3(3-0) F
Prerequisite: MA 521

A study of groups, rings and modules. Elements of homology. Polynomials, Noetherian rings, Algebraic extensions, Galois Theory.

MA 621 MODERN ALGEBRA II 3(3-0) S
Prerequisite: MA 620

A study of linear maps, bilinear forms, representations, multilinear products, semisimplicity and the representation of finite groups.

MA 622 LINEAR TRANSFORMATIONS AND MATRIX THEORY 3(3-0) F
Prerequisite: MA 405

Vector spaces, linear transformation and matrices, minimal polynomials, elementary divisors, canonical forms, quadratic forms, functions of matrices.

MA 623 THEORY OF MATRICES AND APPLICATIONS 3(3-0) S
Prerequisite: MA 622

Generalized inverses, matrix equations, variational methods for eigenvalues,

matrix norms, perturbation of linear systems, computational methods, applications to differential equations, Markov chains.

MA 626 ALGEBRAIC TOPOLOGY 3(3-0) S
Prerequisite: MA 605

Simplicial and singular homology and cohomology, the Eilenberg-Steenrod axioms, duality, cohomology operations; higher homotopy groups, Hurewicz homomorphisms. (Offered 1972-73 and alternate years.)

MA 628 GENERAL TOPOLOGY 3(3 0) S
Prerequisite: MA 604

Comparisons of topologies on function spaces; Ascoli Theorems; Stone Weierstrass Theorems; uniform spaces and completions; paracompactness and partitions of unity; an introduction to a special topic such as topological vector spaces or topological groups.

MA 632 OPERATIONAL MATHEMATICS I 3(3-0) F
Prerequisite: MA 513 or MA 611

Laplace transform with theory and application to ordinary and partial differential equations arising from problems in engineering and physics.

MA 633 OPERATIONAL MATHEMATICS II 3(3-0) S
Prerequisite: MA 632

Extended development of the Laplace and Fourier transforms and their application to the solution of ordinary and partial differential equations, integral equations and difference equations; Z-transforms, other infinite and finite transforms and their applications.

MA 634 THEORY OF DISTRIBUTIONS 3(3-0) F
Prerequisite: MA 632 or consent of instructor

Basic definitions and properties of testing functions and distributions in one or more variables, convergence and calculus of distributions, test functions of rapid descent and distributions of slow growth, convolution, Fourier transforms, applications in the area of differential and difference equations, etc. (Offered 1972-73 and alternate years.)

MA 635 NUMERICAL ANALYSIS III 3(3-0) S
Prerequisites: MA 405, MA 528 (CSC 528)

Topics in advanced numerical analysis such as approximation and evaluation of functions, numerical solution of integral and other operator equations, and numerical solutions of boundary value problems for partial differential equations. Particular attention is given to procedures suitable for implementation on a digital computer, and the computer is used for the solution of selected problems.

MA 637 DIFFERENTIABLE MANIFOLDS 3(3-0) F
Prerequisite: MA 405, MA 521
Corequisite: MA 604

An introduction to the topology and geometry of differentiable manifolds. Multilinear algebra, exterior differential forms, differentiable manifolds, theory of connexions, Riemannian manifolds. (Offered 1971-72 and alternate years.)

MA 641 CALCULUS OF VARIATIONS AND THEORY OF OPTIMAL CONTROL I 3(3-0) F
Prerequisites: MA 512 or MA 426, MA 532

Normed linear function spaces and Frechet differential, theory of the first variation, theory of fields and Weierstrass' excess function, Hamilton-Jacobi

theory and dynamic programming, terminal control problems and the maximum principle. (Offered 1972-73 and alternate years.)

MA 642 CALCULUS OF VARIATIONS AND THEORY OF OPTIMAL CONTROL II 3(3-0) S
Prerequisite: MA 641

The homogeneous problem, the general control problem of Mayer, isoperimetric problems, theory of the second variation, existence of extrema, direct methods of the calculus of variations. (Offered 1972 73 and alternate years.)

MA 647 FUNCTIONAL ANALYSIS I 3(3-0) F

Prerequisite: MA 516

Banach spaces; linear functionals; linear operators, uniform boundedness, open mapping and closed graph theorems; dual spaces; weak topologies.

MA 648 FUNCTIONAL ANALYSIS II 3(3-0) S
Prerequisite: MA 647

Advanced topics in functional analysis such as linear topological spaces; Banach algebra, spectral theory and abstract measure theory and integration.

MA 655 (PY 655) QUALITATIVE METHODS IN CELESTIAL MECHANICS 3(3-0) F
Prerequisites: MA 532, MA 513

Transformation theory in Lagrangian and Hamiltonian mechanics, singularities in N-body problem, regularization, Hill's equation, periodic orbits, fixed point methods, stability.

MA 656 (PY 656) PERTURBATION THEORY IN CELESTIAL MECHANICS 3(3-0) S
Prerequisites: MA 555 (PY 555) or MA 532 and PY 503

Hamilton-Jacobi equation; canonical perturbation theory; resonance problems; adiabatic invariants, asymptotic properties.

MA 661 DIFFERENTIAL GEOMETRY AND TENSOR ANALYSIS I 3(3-0) F
Prerequisite: MA 426 or MA 512

Concepts of classical and modern differential geometry presented from the point of view of tensor analysis and differential forms. Topics to include: theory of curves, tensor analysis and differential forms, intrinsic and extrinsic geometry of surfaces, Riemannian geometry.

MA 662 DIFFERENTIAL GEOMETRY AND TENSOR ANALYSIS II 3(3-0) S
Prerequisite: MA 661

Continuation of MA 661.

MA 681 SPECIAL TOPICS IN REAL ANALYSIS 1-6

MA 682 SPECIAL TOPICS IN COMPLEX ANALYSIS 1-6

MA 683 SPECIAL TOPICS IN ALGEBRA 1-6

MA 684 SPECIAL TOPICS IN COMBINATORIAL ANALYSIS 1-6

MA 685 SPECIAL TOPICS IN NUMERICAL ANALYSIS 1-6

MA 686 SPECIAL TOPICS IN TOPOLOGY 1-6

MA 687 SPECIAL TOPICS IN GEOMETRY 1-6

MA 688 SPECIAL TOPICS IN DIFFERENTIAL EQUATIONS 1-6

MA 689 SPECIAL TOPICS IN APPLIED MATHEMATICS 1-6

The subject matter in the special topics courses varies from year to year. The topics and instructors are announced well in advance by the department.

MA 692 (IE 692, OR 692) SPECIAL TOPICS IN MATHEMATICAL PROGRAMMING 3(3-0) FS Sum.
(See industrial engineering, page 194.)

MA 699 RESEARCH Credits Arranged

Individual research in mathematics.

Mathematics and Science Education

GRADUATE FACULTY

Professor HERBERT E. SPEECE, *Head*
Professor: NORMAN D. ANDERSON; *Associate Professors:* JOHN R. KOLB, HENRY A. SHANNON; *Assistant Professor:* WILLIAM M. WATERS, JR.

The Department of Mathematics and Science Education offers graduate work leading to the degrees of Master of Science, Master of Education and Doctor of Philosophy with majors in mathematics education or science education. Each student's program is individually planned by a graduate committee and will reflect his undergraduate and graduate preparation, teaching experience and future professional plans. Areas of specialization include mathematics, biological science, earth science, chemistry and physics for a master's degree. A minimum of 36 semester hours is required, of which 60 percent must be in the area of subject matter specialization and 20 percent in professional education. Candidates for the Master of Education degree are required to submit a scholarly research paper or otherwise demonstrate competency in educational research. Candidates for the Master of Science degree must conduct an investigation culminating in a thesis. The Master of Science degree also requires a reading knowledge of one foreign language if needed for research efforts. Doctoral students are required to have a reading knowledge of two modern foreign languages or a knowledge in one and competency in a communication tool such as computer science. Comprehensive examinations are required, consisting of a written exposition on both subject area and professional education and an oral examination. Independent reading and participation in seminars are an indispensable part of the doctoral program. The heart of the doctoral program is the dissertation. It must be original research resulting in a significant contribution to science education or mathematics education and should be worthy of publication in the current literature. The dissertation must be defended at the final oral examination.

Applicants must meet the admissions requirements of the Graduate School of North Carolina State University. In addition, they must have the approval of the Department of Mathematics and Science Education. To be admitted to a master's program without subject matter deficiencies, applicants must have completed a degree in which they reached a level of undergraduate work closely approximating

the following minimum: two years of English, one year of physics, one year of chemistry, one and one-half years in the historical-philosophical and psychological foundations of education. In addition to the above, those specializing in mathematics should have had three years of mathematics; those specializing in science should have had one year of biology, one and preferably two years of mathematics and two years of advanced work in one of the sciences.

FOR GRADUATES AND ADVANCED UNDERGRADUATES

ED 511 IMPLICATIONS OF MATHEMATICAL CONTENT, STRUCTURE AND PROCESSES FOR THE TEACHING OF MATHEMATICS IN THE ELEMENTARY SCHOOL 3(3-0) F
Prerequisites: Bachelor's degree in elementary education or permission of instructor

A course designed for teachers and supervisors of mathematics in the elementary school. Special emphasis is given to the implications of mathematical content, structure and processes in teaching arithmetic and geometry in the elementary school.

ED 512 ACTIVE LEARNING APPROACHES TO TEACHING MATHEMATICS IN THE ELEMENTARY SCHOOL 3(3 0) S
Prerequisite: Bachelor's degree in elementary education or permission of instructor

A course that will stress active learning approaches to the teaching of mathematics in the elementary school. Special emphasis will be given to the laboratory approach to teaching mathematics and the use of manipulative materials and activities of the Nuffield Project, the Madison Project, Dienes, Cuisenaire and Gattegno.

ED 592 SPECIAL PROBLEMS IN MATHEMATICS TEACHING 3(0 3) FS
Prerequisite: ED 471 or equivalent

An investigation of current problems in mathematics teaching, with emphasis on the areas of curriculum, methodology, facilities, supervision and research. Specific problems will be studied in depth. Opportunities will be provided to initiate research studies.

ED 594 SPECIAL PROBLEMS IN SCIENCE TEACHING 3(0 3) FS
Prerequisite: ED 476 or equivalent

An investigation of current problems in science teaching with emphasis on areas of curriculum, methodology, facilities, supervision and research. Specific problems will be studied in depth. Opportunities will be provided to initiate research studies.

FOR GRADUATES ONLY

ED 603 TEACHING MATHEMATICS AND SCIENCE IN HIGHER EDUCATION 3(3-0) F
Prerequisites: ED 592 or ED 594, graduate standing, consent of instructor

Collegiate mathematics and science instruction is examined with respect to the nature and philosophy of mathematics and science, objectives, psychological foundations, design of curricula, study of innovative college mathematics and science programs and facilities, selection of instructional strategies, modes of instruction, and sequencing of instruction through learning hierarchies.

ED 604 CURRICULUM DEVELOPMENT AND EVALUATION IN SCIENCE AND MATHEMATICS 3(3-0) FS
Prerequisites: 500-level statistics, ED 615 or PSY 535, consent of instructor

This course deals with the areas of development, evaluation and research in mathematics and science education. Research and evaluation strategies and techniques are reviewed, but emphasis is placed on the derivation of rationales and the clear definition of problem areas that are specific to research in learning and teaching mathematics and science. Groups of students are expected to complete a project in MED or SED of either a developmental, or an evaluative, or a research nature suitable for publication.

ED 605 EDUCATION AND SUPERVISION OF TEACHERS OF MATHEMATICS AND SCIENCE 3(3-0) S
Prerequisites: ED 470 or ED 475 or equivalent, ED 592 or ED 594

A course designed to develop the capability of effective improvement and alteration of the teaching behavior of mathematics and science teachers. Requires the student to structure materials, conditions and environmental settings for training mathematics and science teachers; to specify outcomes as observable teacher performance; and to assess the extent to which desired teacher performance in mathematics and science are produced by the particular training procedure. Students will be given an opportunity to work with the training of preservice mathematics and science teachers during their instruction in methods.

ED 690 SEMINAR IN MATHEMATICS EDUCATION 2 FS
Prerequisite: Departmental major or consent of instructor.

An in depth examination and analysis of the literature and research in a particular topic(s) in mathematics education. Students will be expected to make presentations to the faculty and class on the topic under consideration.

ED 695 SEMINAR IN SCIENCE EDUCATION 2 FS
Prerequisite: Departmental major or consent of instructor.

An in-depth examination and analysis of the literature and research in a particular topic(s) in science education. Students will be expected to make presentations to the faculty and class on the topic under consideration.

Mechanical and Aerospace Engineering

GRADUATE FACULTY

Professor ROBERT W. TRUITT, *Head*
Professor CARL F. ZOROWSKI, *Associate Head*
Professors: N. WHITE CONNER, FRED R. DEJARNETTE, JESSE S. DOOLITTLE, *Graduate Administrator*, BERTRAM H. GARCIA, JR., FRANCIS J. HALE, FRANKLIN D. HART, HASSAN A. HASSAN, RICHARD B. KNIGHT, M. NECATI OZISIK, JOHN N. PERKINS, FREDERICK O. SMETANA, JAMES E. SUNDERLAND, JAMES C. WILLIAMS, III, JAMES WOODBURN; *Adjunct Professors:* RANDALL M. CHAMBERS, ROBERT W. GRAHAM; *Associate Professors:* JOHN A. BAILEY, ROLIN F. BARRETT, CLIFFORD J. MOORE, JR., JAMES C. MULLIGAN, LARRY H. ROYSTER, JOHN K. WHITFIELD; *Visiting Associate Professor:* ELSAYED M. AFIFY; *Adjunct Associate Professor:* E. CARSON YATES, JR.; *Assistant Professors:* DONALD W. COTT, JAMES A. DAGGERHART, JR., THOMAS B. LEDBETTER,

LALJI J. PAVAGADHI; *Visiting Assistant Professor:* JAMES R. BAILEY; *Adjunct Assistant Professor:* G. LOUIS SMITH

The Department of Mechanical and Aerospace Engineering offers graduate study leading to the Master of Mechanical Engineering, Master of Science and Doctor of Philosophy degrees. Entrance to the various programs in the department is normally based upon a pertinent, accredited baccalaureate degree.

At present the major emphases in graduate study are thermal sciences, including classical thermodynamics, statistical thermodynamics, heat transfer, transport phenomena, cryogenics and direct energy conversion; gas-dynamics, including dynamics of compressible fluids, dynamics of viscous fluids, aerothermochemistry, plasmadynamics and rarefied gasdynamics; mechanical sciences, including vibrations, acoustics, mechanical transients, airframe dynamics, design synthesis, analysis and optimization, materials processing, fiber mechanics; aerospace sciences, including aerodynamics, chemical and electrical propulsion and flight vehicle design.

The professional technological interests of the department are represented by graduate courses in air-conditioning design, lubrication, inertial navigation, photoelasticity, experimental stress analysis and machine design.

Extensive laboratory facilities, including a helium cryostate, 48″ oil diffusion pumps, 8″ x 10″ continuous flow hypersonic wind tunnel, 7″ x 7″ continuous flow transonic wind tunnel and 6″ x 6″ blowdown supersonic wind tunnel are available for research and training in the area of plasmagasdynamics, rarefied gasdynamics, boundary layers and heat transfer, aerodynamics and cryogenics. A modern laboratory for the study of vibrations and acoustics is also available. Recent developments include extensive laboratory facilities in heat transfer, direct energy conversion, vehicle propulsion, materials processing and fiber mechanics. These experimental facilities coupled with availability of an IBM Model 370/165 computer provide the graduate students with outstanding research tools.

A new Graduate Systems Design Facility is available to carry out multidisciplinary and interdisciplinary programs in a variety of societal problem areas. The fundamental objective of graduate study in this field is to prepare the student for leadership in the various areas of research, teaching and design. The graduate student is placed in close association with members of the graduate faculty both in individual research and design team activities. Participation in a research or team design project as a research assistant or employment as a teaching assistant is regarded as significant experience during residence.

FOR ADVANCED UNDERGRADUATES

MAE 401 ENERGY CONVERSION 3(3 0) FS
Prerequisite: MAE 302

Applications of the principles of thermodynamics, fluid mechanics, heat transfer and combustion to power generation. Both the conventional and direct energy conversion methods are studied as to the principles involved and the feasibility and limitations of each method. Consideration is given to the economics of power generation.

MAE 402 HEAT AND MASS TRANSFER 3(3-0) FS
Prerequisites: MAE 302, MA 301

A study of the fundamental relationships of steady and transient heat transfer by conduction, convection, radiation and during changes of phase: mass transfer by diffusion and convection, simultaneous mass and heat transfer.

MAE 403 AIR CONDITIONING 3(3-0) F
Prerequisite: MAE 302

A fundamental study of summer and winter air conditioning including temperature, humidity, air velocity and distribution.

MAE 404 REFRIGERATION 3(3 0) F
Prerequisite: MAE 302

A thermodynamic analysis of the simple, compound, centrifugal and multiple effect compression systems, the steam jet system and the absorption system of refrigeration.

MAE 405 MECHANICAL ENGINEERING LABORATORY III 1(0-3) F
Prerequisite: MAE 306

The final course in the undergraduate mechanical laboratory sequence which exposes the student to case studies in experimental engineering, and provides him the opportunity to select instrumentation and design a complete experimental set up for a specific problem.

MAE 409 PARTICULATE CONTROL IN INDUSTRIAL ATMOSPHERIC POLLUTION 3(3-0) S
Prerequisite: MAE 301 or equivalent

Combustion calculations and analysis of particulate emission and gases from industrial and utility power stations burning various types of fuel. State and federal pollution codes, requirements for compliance and enforcement. Calculations and design of industrial equipment to combat pollution. Utilization of waste products from industrial plants.

MAE 411 MECHANICAL DESIGN I 3(3 0) F
Prerequisites: MAE 315, MAE 316

Application of the engineering and materials sciences to the analysis and design of mechanical components including screws and fasteners, antifriction and journal bearings, springs, gears, shafts, clutches, breaks and couplings, etc.

MAE 415 MECHANICAL ENGINEERING ANALYSIS 3(3 0) F
Prerequisites: MAE 302, MAE 315, MAE 316, EE 331

Consideration of a logical method of problem solving through the integration of the physical sciences, engineering sciences and mathematics and their use in a rigorous training in methods of analysis of real mechanical engineering problems.

MAE 416 MECHANICAL ENGINEERING DESIGN 4(3-2) S
Prerequisite: MAE 415

Application of the engineering and materials sciences to the total design of mechanical engineering components and systems. Consideration and utilization of the design process including problem definition, solution synthesis, design analysis, optimization and prototype evaluation through design project activity.

MAE 431 THERMODYNAMICS OF FLUID FLOW 3(3-0) F
Prerequisites: MA 301, MAE 302, EM 303, or MAE 355

The fundamental dynamics and thermodynamic principles governing the flow of gases are presented from both theoretical and experimental viewpoints. Mathematical relations are closely correlated with physical phenomena to emphasize the complementary nature of theory and experiment.

MAE 435 PRINCIPLES OF AUTOMATIC CONTROL 3(3-0) FS
Prerequisite: MA 301

Study of linear feedback control systems using transfer functions. Transient and steady-state responses. Stability analysis using rootlocus and frequency response techniques (Bode plots and Nyquist diagrams). Active and passive compensation methods. Preliminary design and analysis of typical mechanical and aerospace automatic control systems.

MAE 462 FLIGHT VEHICLE STABILITY AND CONTROL 3(3 0) F
Prerequisite: MAE 361

Linearized dynamic analysis of the motion of a six degree of-freedom flight vehicle in response to control inputs and disturbance through use of the transfer function concept. Control of dynamic behavior by vehicle design (stability derivatives) and/or flight control systems.

MAE 467 ROCKET PROPULSION 3(3-0) F
Prerequisite: MAE 365

Performance analysis and design of liquid fuel, solid fuel, nuclear and electrical rocket propulsion systems.

MAE 471 (MAS 471) UNDERSEA VEHICLE DESIGN 3(3-0) S

Prerequisite: MAE 355 or EM 303

An introduction to the solution of problems encountered in the design of both submerged and semisubmerged ocean vehicles. Included are discussions and analytical treatments of vehicle drag and lift, buoyancy effects, vehicle propulsion and systems integration.

MAE 472 AEROSPACE VEHICLE STRUCTURES II 4(3-3) F
Prerequisite: MAE 371

A continuation of MAE 471 with emphasis on specialized topics such as semi nomocoque structures, deflection of structures, indeterminate structures, torsion analysis. A laboratory is included to demonstrate the theory and application of resistance strain gages, and to provide an opportunity for actual load-stress-deflection tests on typical flight vehicle structure components, as well as the determination of basic material properties, and correlation of tests and analytical results.

MAE 474 MATRIX STRESS AND DEFORMATION ANALYSIS 3(3-0)
Prerequisite: MAE 316 or MAE 371 or EM 307 or EM 301

Development of the fundamentals and application of matrix methods of stress and deformation analysis for load carrying components typical of aerospace and mechanical engineering systems. Mr. Garcia

MAE 479 AEROSPACE VEHICLE DESIGN 4(2-6) S
Prerequisites: MAE 356, MAE 462, MAE 467, MAE 472, EE 332

A synthesis of all previously acquired theoretical and empirical knowledge and application to the design of practical aerospace vehicle systems.

MAE 495 TECHNICAL SEMINAR IN MECHANICAL AND AEROSPACE ENGINEERING 1(1-0) FS
Prerequisite: Senior standing

Meetings once a week for the delivery and discussion of student papers on topics of current interest in mechanical engineering.

FOR GRADUATES AND ADVANCED UNDERGRADUATES

MAE 501 STEAM AND GAS TURBINES 3(3-0) FS
Prerequisites: MAE 302, EM 303 or MAE 355

Fundamental analysis of the theory and design of turbomachinery flow passages; control and performance of turbomachinery; gas turbine engine processes.
Mr. Doolittle

MAE 507, 508 INTERNAL COMBUSTION ENGINE FUNDAMENTALS 3(3-0) FS
Prerequisite: MAE 302

The fundamentals common to internal combustion engine cycles of operation. The Otto engine: carburetion, fuel distribution, flame and spark timing, and altitude effects; the Diesel engine; injection knock, combustion, precombustion and scavenging as applied to reciprocating and rotary engines. Mr. Ledbetter

MAE 510 THEORY OF PARTICULATE COLLECTION IN AIR POLLUTION CONTROL 3(3 0) S
Prerequisite: MAE 409 or graduate standing

Particulate matter is classified and its properties are described. The motion of particles as applied to particulate collection is carefully analyzed. The elements of aerodynamic capture of particles are developed and applications in filteration and liquid scrubbing are considered. Fundamentals of acoustical, electrostatic and thermal precipitation are introduced. Sampling techniques and instrumentation are also considered. Mr. Afify

MAE 513 VIBRATION AND NOISE CONTROL 3(2-3) F
Prerequisite: MAE 315 or MAE 472

This course will be devoted to a study of the nature and origin of vibration and noise in mechanical systems and design for their control. Considerations will include source reduction, isolation, transmission, damping and acoustic shielding techniques, through classroom discussions and laboratory demonstrations. Mr. Hart

MAE 515 EXPERIMENTAL STRESS ANALYSIS 3(2 3) F

Prerequisite: MAE 316

Theoretical and experimental techniques of strain and stress analysis with emphasis on electrical strain gages and instrumentation, brittle coatings, grid methods and an introduction to photoelasticity. Laboratory includes an investigation and complete report of a problem chosen by the student under the guidance of the instructor. Mr. Whitfield

MAE 516 PHOTOELASTICITY 3(2-3) S
Prerequisite: MAE 316

Theory and experimental techniques of two- and three- dimensional photoelasticity including photoelastic coatings, photoplasticity and an application of photoelastic methods to the solution of mechanical design problems. Laboratory includes an investigation and complete report of a problem chosen by the student under the guidance of the instructor. Mr. Whitfield

MAE 517 LUBRICATION 3(2-3) S
Prerequisite: EM 303

The theory of hydrodynamic lubrication; Reynold's equation, the Sommerfield integration, effect of variable lubricant properties and energy equation for

temperature rise. Properties of lubricants. Application to design of bearings. Boundary lubrication. Solid film lubrication. Mr. Barrett

MAE 518 ACOUSTIC RADIATION I 3(3-0) FS
Prerequisite: MA 301

Discussion of the principles of acoustic radiation as related to acoustic sources and their related fields. The radiation of single sources (point, plane, line cylinder, spheres, etc.) and combinations thereof are considered. Mr. Royster

MAE 521 AEROTHERMODYNAMICS 3(3-0) FS
Prerequisites: MAE 301, MAE 355 or EM 303

Review of basic thermodynamics pertinent to gas dynamics. Detailed development of the general equations governing gas motion in both differential and integral form. Simplification of the equations to those for specialized flow regimes. Similarity parameters. Applications to simple problems in various flow regimes.
Mr. Perkins

MAE 531 PLASMAGASDYNAMICS I 3(3 0) FS
Prerequisites: MAE 356, PY 414

Study of basic laws governing plasma motion for dense and rarefied plasmas, hydromagnetic shocks, plasma waves and instabilities, simple engineering applications. Mr. Hassan

MAE 532 PLASMAGASDYNAMICS II 3(3 0) FS
Prerequisite: MAE 531

Quantum statistics and ionization phenomena. Charged particles interactions. Transport properties in the presence of electric and magnetic fields and non-equilibrium ionization. Mr. Hassan

MAE 535 (EE 535) GAS LASERS 3(3 0) FS
Prerequisites: MAE 356 or equivalent, PY 407

Study of the principles, design and potential applications of ion, molecular, chemical and atomic gas lasers. Mr. Hassan

MAE 541, 542 AERODYNAMIC HEATING 3(3-0) FS
Prerequisites: MA 511, MAE 521

A detailed study of the latest theoretical and experimental findings of the com pressible laminar and turbulent boundary layers with special attention to the aerodynamic heating problem. Application of theory in the analysis and design of aerospace hardware. Mr. Truitt

MAE 543 HEAT TRANSFER THEORY AND APPLICATIONS 3(3 0) FS
Prerequisite: MAE 402 or equivalent

Development of basic equations for steady and transient heat and mass transfer processes. Emphasis is placed on the application of the basic equations to engineering problems in the areas of conductions, convection, mass transfer and thermal radiation. Mr. Moore

MAE 545, 546 PROJECT WORK IN MECHANICAL ENGINEERING I, II 2(0-4) FS

Individual or small group investigation of a problem stemming from a mutual student-faculty interest. Emphasis is placed on providing a situation for exploiting student curiosity. Graduate Staff

MAE 550 CRYOGENICS I 3(3-0) FS
Prerequisite: MAE 402

A study of the thermodynamic processes required to produce cryogenic fluids.

Properties of materials at cryogenic temperatures. Insulation of cryogenic vessels and lines. Design of cryogenic systems. Mr. Smetana

MAE 554 ADVANCED AERODYNAMIC THEORY 3(3-0) S
Prerequisite: MAE 355

Development of fundamental aerodynamic theory. Emphasis upon mathematical analysis and derivation of equations of motion, airfoil theory and comparison with experimental results. Introduction to supersonic flow theory. Mr. DeJarnette

MAE 555 ADVANCED FLIGHT VEHICLE STABILITY AND CONTROL 3(3-0) F
Prerequisite: MAE 462

Preliminary analysis and design of flight control systems to include autopilots and stability argumentation systems. Study of effects of inertial cross-coupling and nonrigid bodies on vehicle dynamics. Mr. Hale

MAE 562 ADVANCED AIRCRAFT STRUCTURES 3(3-0) S
Prerequisite: MAE 371

Development of methods of stress analysis for aircraft structures, special problems in structural design, stiffened panels, rigid frames, indeterminate structures, general relaxation theory. Mr. Garcia

MAE 571 INERTIAL GUIDANCE, DESIGN AND ANALYSIS 3(3-0) S
Prerequisites: MA 401, MAE 435 or MAE 462

Engineering design and performance analysis of inertial guidance components, subsystems and systems. Development of transfer functions and application of linear system techniques to determine stability, transient response and steady-state errors or gyros, accelerometers, stable platforms and initial alignment subsystems. Error analysis and its significance. Preliminary design and analysis of typical inertial guidance systems for flight and marine vehicles. Mr. Hale

MAE 581, 582 HYPERSONIC AERODYNAMICS 3(3-0) FS
Prerequisites: MA 512, MAE 521 or equivalent

A detailed study of the latest theoretical and experimental findings in hypersonic aerodynamics. Mr. Truitt

MAE 593 SPECIAL TOPICS IN MECHANICAL ENGINEERING 3(3-0) FS
Prerequisite: Advanced undergraduate or graduate standing

Faculty and student discussions of special topics in mechanical engineering.
Graduate Staff

FOR GRADUATES ONLY

MAE 601 ADVANCED ENGINEERING THERMODYNAMICS 3(3-0) F
Prerequisites: MAE 302; MA 401 or MA 511

Thermodynamics of a general reactive system; conservation of energy and the principles of increase of entropy; the fundamental relation of thermodynamics; Legendre transformations; equilibrium and stability criteria in different representations; general relations; chemical thermodynamics; multireaction system; ionization; irreversible thermodynamics; the Onsager relation; applications to thermoelectric, thermomagnetic and diffusional processes. Mr. Moore

MAE 602 STATISTICAL THERMODYNAMICS 3(3-0) S
Prerequisite: MAE 601

Fundamental principles of kinetic theory, quantum mechanics, statistical mechanics and irreversible phenomena with particular reference to thermo-

dynamics systems and processes. The conclusions of the classical thermodynamics are analyzed and established from the microscopic viewpoint. Mr. Moore

MAE 603 ADVANCED POWER PLANTS 3(3 0) F
Prerequisite: MAE 401

A critical analysis of the energy balance of thermal power plants, thermodynamics and economic evaluation of alternate schemes of developments; study of recent developments in the production power. Mr. Doolittle

MAE 605 AEROTHERMOCHEMISTRY 3(3 0) S
Prerequisites: MA 511; MAE 601 or equivalent

A generalized treatment of combustion thermodynamics including derivation of thermodynamic quantities by the method of Jacobians, criteria for thermodynamic equilibrium, computation of equilibrium composition and adiabatic flame temperature. Introduction to classical chemical kinetics. Conservation equations for a reacting system, detonation and deflagration. Theories of flame propagation, flame stabilization and turbulent combustion. Mr. Perkins

MAE 606 ADVANCED GAS DYNAMICS 3(3-0) S
Prerequisites: MA 511, MAE 521, MAE 601

The general conservation equations of gas dynamics from a differential and integral point of view. Hyperbolic compressible flow equations, unsteady one-dimensional flows, the nonlinear problem of shock wave formation, isentropic flow, flow in nozzles and jets, turbulent flow. Mr. Smetana

MAE 608 ADVANCED HEAT TRANSFER I 3(3 0) F
Prerequisites: MA 512, MAE 402

A generalized treatment of the methods of solution of transient and steady heat conduction in finite and infinite regions involving internal heat generation. Approximate methods and similarity transformation in the solution of heat conduction problems involving change of phase, variable thermal properties and nonlinear thermal radiation boundary conditions. Heat conduction in multilayer regions and in anisotropic solids. Solutions with numerical methods. Mr. Ozisik

MAE 609 ADVANCED HEAT TRANSFER II 3(3-0) S
Prerequisite: MAE 608

Advanced topics in steady and transient natural and forced convection heat transfer for laminar and turbulent flow of incompressible fluid through conduits and over bodies. Problems involving variable properties and interaction with thermal radiation. Mass transfer in laminar and turbulent flow; simultaneous heat and mass transfer. Mr. Sunderland

MAE 610 ADVANCED TOPICS IN HEAT TRANSFER 3(3-0) S
Prerequisite: MAE 609

This course constitutes a study of recent developments in heat transfer and related areas. It is anticipated that the course content will change from semester to semester. Mr. Ozisik

MAE 611, 612 ADVANCED MACHINE DESIGN I, II 3(3-0) FS
Prerequisite: MAE 416

An advanced integrated treatment of stress analysis and materials engineering devoted to current rational methods of analysis and design applicable to mechanical components. Primary attention placed on the determination and prediction of strength, life and deformation characteristics of machine components as dictated by performance requirements. Messrs. Garcia, Zorowski

MAE 613 MECHANICS OF MACHINERY 3(3-0) F
Prerequisites: MAE 315, MA 512

Advanced applications of dynamics to the design and response analysis of dynamic behavior of machines and mechanical devices. Emphasis on developing competence in transforming real problems in dynamics into appropriate mathematical models whose analysis permits performance predictions of engineering value.
Messrs. Hart, Whitfield

MAE 614 MECHANICAL TRANSIENTS AND MACHINE VIBRATIONS 3(3-0) S
Prerequisites: MAE 315 or EM 555; MA 512

A study of the forces and motions produced in mechanical systems by periodic and transient inputs including shock and impact loading. Particular attention devoted to the application of the principles of vibration theory to problems encountered in mechanical design. Messrs. Hart, Whitfield

MAE 615 AEROELASTICITY I 3(3-0) F
Prerequisites: MA 511; MAE 411 or MAE 472, MAE 521

Deformations of aerostructures under static and dynamic loads, natural mode shapes and frequencies; two and three-dimensional incompressible flow, wings and bodies in unsteady flow; static aeroelastic phenomena. Mr. Garcia

MAE 617 MECHANICAL SYSTEMS DESIGN ANALYSIS 3(3-0) F
Prerequisites: MAE 611, MAE 613

Lecture and project activity devoted to development of the ability to apply knowledge and experience in performing comprehensive design analysis of complete mechanical systems. Areas of interest to include critical problem recognition, system modeling, performance determination, and optimization and reliability evaluation. Mr. Zorowski

MAE 618 MECHANICAL SYSTEM DESIGN SYNTHESIS 3(3-0) S
Prerequisite: MAE 617

Application of the basic philosophy and methodology of the complete design process to advanced mechanical system design. Individual and group experience in the conception, synthesis, analysis, optimization and implementation phases of feasibility, preliminary and final design studies provided by means of comprehensive system design projects. Mr. Zorowski

MAE 619 RANDOM VIBRATION 3(3-0) F or S
Prerequisite: MAE 614

Mathematical description of stochastic processes. The stationary and ergodic assumptions and response analysis of mechanical systems to random excitation. Simulation of and failure due to random environments. Mr. Hart

MAE 622 ACOUSTIC RADIATION II 3(3-0) F or S
Prerequisite: MAE 518

Introduction to the various numerical methods for determining and near-and-far-field pressures for arbitrary shaped bodies. The methods of Chertock, Hess, Copley, Schenck and Pachner are considered. Mr. Royster

MAE 625, 626 DIRECT ENERGY CONVERSION 3(3-0) FS
Prerequisite: MAE 601

An engineering study of the modern developments in the field of conversion of heat to power in order to meet new technology demands. Thermoelectric, thermomagnetic, thermionic, photovoltaic and magnetohydrodynamic effects and their

utilization for energy conversion purposes, static and dynamic response, limitations imposed by the first and the second laws of thermodynamics. Energy and entropy balances, irreversible sources; inherent losses, cascading, design procedures, experimental studies to determine the response and efficiency of various systems.
Mr. Moore

MAE 631 APPLICATIONS OF ULTRASONICS TO ENGINEERING RESEARCH 3(3-0) F
Prerequisites: EE 332, MA 511

The technique and theory of propagation of ultrasonics in liquids, gases and solids. Development of ultrasonic transducers, the elastic piezoelectric and dielectric relationships. Ultrasonic applications of asdic or sonar cavitation, emulsification, soldering, welding and acoustic properties of gases, liquids and solids.
Mr. Woodburn

MAE 651 PRINCIPLES OF FLUID MOTION 3(3-0) F
Prerequisite: MAE 554
Corequisite: MA 511

Fundamental principles of fluid dynamics. Mathematical methods of analysis are emphasized. Potential flow theory development with introduction to the effects of viscosity and compressibility. Two dimensional and three-dimensional phenomena are considered. Mr. DeJarnette

MAE 652 DYNAMICS OF COMPRESSIBLE FLOW 3(3-0) F
Prerequisites: MA 511, MAE 521

Properties of compressible fluids, equation of motion in one dimensional motion, channel flows, shock wave theory, methods of observation and flows at transonic speeds. Mr. Williams

MAE 653 SUPERSONIC AERODYNAMICS 3(3 0) S
Prerequisite: MAE 521

Equations of motion in supersonic flow, Prandtl-Meyer turns, method of characteristics, hodograph plane, supersonic wind tunnels, supersonic airfoil theory and boundary layer shock interaction. Mr. Perkins

MAE 654 DYNAMICS OF VISCOUS FLUIDS I 3(3-0) F
Prerequisite: MAE 521

Exact solutions to the Navier-Stokes Equations. Approximate solutions for low Reynolds numbers. Approximate solutions for high Reynolds numbers—incompressible boundary theory. Laminar and turbulent boundary layers in theory and experiment. Flows separation. Mr. Williams

MAE 655 DYNAMICS OF VISCOUS FLUIDS II 3(3-0) S
Prerequisite: MAE 654

A continuation of MAE 654. Compressible laminar and turbulent boundary layers. Laminar and turbulent jets. The stability of laminar boundary layers with respect to small disturbances, transition from laminar to turbulent flow.
Mr. Williams

MAE 657 MEASUREMENT IN RAREFIED GAS STREAMS 3(3-0) F
Prerequisite: MAE 602

A study of the basis for measurement of flow properties in rarefied gas streams. Included will be ionization gauges, hot wire anemometers and temperature probes, pitot and static tubes, Langmuir probes, electron scattering and electron beam density gauges. Mr. Smetana

MAE 658, 659 MOLECULAR GAS DYNAMICS 3(3-0) FS
Prerequisites: MAE 521, MAE 602

Statistical mechanics as applied to the derivation of the equations of gas-dynamics from the microscopic viewpoint. Energy levels of atoms and molecules and their relation to equilibrium thermodynamic concepts, in particular, specific heats. Approximate solutions of the Boltzmann Equation. Treatments of viscosity, heat conduction and electrical conductivity. Collision processes. High-temperature behavior of multi-species gas mixtures. Mr. Williams

MAE 661, 662 AEROSPACE ENERGY SYSTEMS 3(3 0) FS
Prerequisites: MA 512, MAE 521; PY 407, or equivalent

A study of energy systems appropriate to the varied requirements of space operations. Includes analysis of chemical, nuclear and solar energy sources and the theory of their adaptation to operational requirements for propulsion and auxiliary power, cooling requirements, coolants and materials. Mr. Truitt

MAE 663 (TX 663) MECHANICS OF TWISTED STRUCTURES 3(3-0) F
(See textile technology, page 316.)

MAE 664 (TX 664) MECHANICS OF FABRIC STRUCTURES 3(3-0) S
(See textile technology, page 316.)

MAE 671, 672 ADVANCED AIR CONDITIONING DESIGN I, II 3(3-0) FS
Prerequisites: MAE 403, MAE 404

The design of heating and air-conditioning systems; the preparation of specifications and performance tests on heating and air-conditioning equipment.
Mr. Knight

MAE 674, 675 ADVANCED SPACECRAFT DESIGN 3(3-0) FS
Prerequisites: MAE 542, MAE 582

Analysis and design of spacecraft including system design criteria, acceleration tolerance, entry environment, thermal requirements, criteria for configuration design, aerodynamic design, heating rates, thermostructural design, boost phase, de-orbit, entry corridor, lift modulation, rolling entry, glide phase, maneuvering and landing, stability and control, thermal protection system, materials, instrumentation and life support systems. Mr. Truitt

MAE 681 INTRODUCTION TO ROCKET PROPULSION 3(3-0) F
Prerequisite: MAE 601

Review of the exterior ballistics and performance of rocket-propelled vehicles. Thermodynamics of real gases at high temperature. Nonequilibrium flow in rocket nozzles. Mr. Perkins

MAE 682 SOLID PROPELLANT ROCKETS 3(3-0) S
Prerequisite: MAE 681

A study of the design and performance of solid-propellant rockets; properties and burning characteristics of solid propellants. Internal ballistics of solid propellant rockets. Design and design optimization. Combustion instabilities.
Mr. Hassan

MAE 683 LIQUID PROPELLANT ROCKETS 3(3-0) S
Prerequisite: MAE 681

The study and design of liquid-propellant rockets. Combustion of liquid fuels. Thrust chamber, propellant supply and injection system. Cooling of rocket motors. Low- and high-frequency instability in liquid rocket motors. Scaling laws.
Mr. Hassan

MAE 684 ION PROPULSION 3(3-0) F or S
Prerequisite: MAE 531

Study and design of ion motors, power sources and converters, missions for ion-propelled vehicles. Mr. Hassan

MAE 693 ADVANCED TOPICS IN MECHANICAL ENGINEERING 1-6 F or S
Prerequisite: Graduate standing

Faculty and graduate student discussions of advanced topics in contemporary mechanical engineering. Graduate Staff

MAE 695 MECHANICAL ENGINEERING SEMINAR 1(1-0) F or S

Faculty and graduate student discussions centered around current research problems and advanced engineering theories. Graduate Staff

MAE 699 MECHANICAL ENGINEERING RESEARCH Credits Arranged
Prerequisites: Graduate standing in mechanical engineering, consent of adviser

Individual research in the field of mechanical engineering. Graduate Staff

Meteorology

(For a listing of graduate faculty and departmental information, see geosciences, page 171.)

FOR ADVANCED UNDERGRADUATES

MY 411 INTRODUCTORY METEOROLOGY 3(3-0) F
Prerequisites: PY 206, PY 208 or PY 212; MA 201 or MA 212

The physical setting: coordinates, planetary motion, gravitation; composition and structure of the atmosphere; insolation and diurnal phenomena; heat balance of the atmosphere; consequent distribution of variables of state, motion and weather.

MY 412 ATMOSPHERIC PHYSICS 3(3-0) S
Prerequisite: MY 411 or consent of instructor

Atmospheric effects on electromagnetic and acoustic transmission, and the consequent phenomena; terrestrial radiation; radar meteorology; visibility; atmospheric electricity and magnetism.

MY 421 ATMOSPHERIC STATICS AND THERMODYNAMICS 3(3-0) F
Prerequisites: PY 206, PY 208 or PY 212; MA 202

The variables of state and thermodynamics of dry and moist air in the atmospheric system; water phase changes; hydrostatics and altimetry; stability, convection and diffusion; transfers at the surface; natural modifications of air.

MY 422 ATMOSPHERIC KINEMATICS AND DYNAMICS 3(3-0) S
Prerequisites: PY 207 or PY 208; MA 202
Corequisite: MY 421 or consent of instructor

Properties and fields of atmospheric motion, and variations with time; forces and force fields; equilibrium and accelerated motions; the boundary layer and momentum transfer; continuity, pressure tendency and divergence vorticity theorems.

MY 435 MEASUREMENTS AND DATA SYSTEMS 3(2-3) S
Prerequisite: MY 421

Meteorological instruments, observations and networks; data communications,

reduction, and presentation; meteorological charts and diagrams; fundamental analysis of physical distributions.

MY 441 METEOROLOGICAL ANALYSIS I 3(3-0) F
Prerequisites: MY 422, MY 435

Theory and analysis of atmospheric distributions, processes and developments in the three space dimensions and time.

MY 443 METEOROLOGICAL LABORATORY I 4(0-10) F
Prerequisite: MY 435
Corequisite: MY 441

Laboratory course in analysis of atmospheric distributions, processes and developments, employing regularly available meteorological data and the principles presented in prerequisite and corequisite courses. The purpose is to gain working knowledge of integrated atmospheric systems and processes through detailed analyses of natural situations.

MY 444 METEOROLOGICAL LABORATORY II 4(0-10) S
Prerequisite: MY 443

Laboratory course in analysis and application of principles and concepts for predicting developments in the weather.

FOR GRADUATES AND ADVANCED UNDERGRADUATES

MY 512 MICROMETEOROLOGY 3(3-0) F
Prerequisite: MY 422

Meteorology of the lowest hundred meters of the atmosphere with emphasis on the transport of momentum, heat, water vapor, and effluents and their transfer through the earth's surface. Mr. Weber

MY 521 THE UPPER ATMOSPHERE 3(3-0) S
Prerequisite: MY 411 or consent of instructor

Meteorological conditions in the upper atmosphere from the stratosphere to the ionosphere. Compositions, mean distributions and variabilities, and circulation and transport properties in the region. Physical theories. Mr. Weber

MY 555 METEOROLOGY OF THE BIOSPHERE 3(3-0) F
Prerequisites: PY 205 or PY 211; CH 103 or CH 107; MA 102 or MA 112

A course designed for graduate students in the life sciences, presenting the physical principles governing the states and processes of the atmosphere in contact with earth's surface of land, water and life. Exchanges of heat, mass and momentum are analyzed for various conditions of the atmosphere and surface, and as a function of season, time and geographic location. Graduate Staff

MY 556 AIR POLLUTION METEOROLOGY 3(3 0) S
Prerequisite: MY 555 or equivalent

The meteorological aspects of air pollution, especially for nonmeteorologists engaged in graduate training for work involving air pollution. Mr. Peterson

MY 593 ADVANCED TOPICS 1-6 FS
Prerequisite: Consent of staff

Special topics of advanced nature in the field of meteorology, provided to groups or assigned to individual students. Graduate Staff

FOR GRADUATES ONLY

MY 612 ATMOSPHERIC RADIATIVE TRANSFER 3(3-0) S
Prerequisite: MY 412

The study of solar and terrestrial radiation. Methods of actinometric measurements, radiation absorption in the atmosphere, scattering of radiation, the solar spectrum, infrared radiative transfer and methods of determining net radiation. Satellite measurement of radiation and determination of atmospheric properties from satellite measurements. Mr. Weber

MY 627 ATMOSPHERIC TURBULENCE AND DIFFUSION 3(3-0) F
Prerequisite: MY 422

Mechanics of turbulence in the atmosphere, spectra and scales of atmospheric turbulence, and magnitudes of turbulent fluctuations. Theories of diffusion in the atmosphere. Diffusion and transport experiments. Processes other than natural turbulence affecting concentration of effluents. Mr. Weber

MY 635 DYNAMICAL ANALYSIS OF THE ATMOSPHERE 3(2-3) F
Prerequisites: MY 441, MY 443

Theory and analysis of circulation and weather systems based on dynamical concepts; structure, movement and development of systems; evaulation of theoretical concepts in prognosis and forecasting. Mr. Saucier

MY 695 SEMINAR 1(1 0) FS
Prerequisite: Graduate standing

Presentation of scientific articles and special lectures. Each student is required to present or critically review one or more papers. Graduate Staff

MY 699 RESEARCH Credit Arranged FS
Prerequisites: Graduate standing and consent of advisory committee

Graduate research in fulfillment of requirements for a graduate degree.
Graduate Staff

Microbiology

GRADUATE FACULTY

Professor JAMES B. EVANS, *Head*
Professors: WALTER J. DOBROGOSZ, GERALD H. ELKAN, PAT B. HAMILTON, JEROME J. PERRY; *Adjunct Associate Professors:* HAROLD L. LEWIS, JERRY J. TULIS; *Assistant Professor:* EDWARD C. HAYES, III

ASSOCIATE MEMBERS OF THE DEPARTMENT

Professors: FRANK B. ARMSTRONG, WILLIAM V. BARTHOLOMEW, JAMES G. LECCE, MARVIN L. SPECK; *Professor USDA:* JOHN L. ETCHELLS; *Associate Professors:* WESLEY E. KLOOS, JOHN J. MCNEILL

The Department of Microbiology offers programs leading to the Master of Science and Doctor of Philosophy degrees. These are research oriented programs

and require a dissertation based on personal research on some basic aspect of the science. Also offered is the professional degree, Master of Microbiology, which does not require a dissertation.

Students applying for admission to the programs need not have had any formal training in microbiology. Applicants should have a bachelor's degree in one of the biological or physical sciences with at least two years of biology (preferably including a semester of microbiology), two years of chemistry (including a year of organic), two years of math (including a year of calculus), a year of physics and two years of a foreign language. Any deficiencies may be made up while in graduate school but will not be counted as credit toward a graduate degree.

There are no specific departmental requirements regarding courses of study. Each program is tailored for the individual student by his graduate advisory committee. There is a core of basic courses in microbiology that will be on the programs of most graduate students. However, at least half of the courses in most programs will be basic courses in related areas such as biochemistry, chemistry, genetics and cell biology.

At least one semester of half-time teaching experience is required of all Ph.D. candidates. All graduate students are expected to attend and participate in the seminar program every semester that they are in residence. As a general rule the M.S. program requires two full years (including summers) beyond the B.S. level and the Ph.D. program requires two or three full years beyond the M.S. level.

FOR ADVANCED UNDERGRADUATES

MB 401 GENERAL MICROBIOLOGY 4(3-3) S
Prerequisites: BS 100, CH 223 or CH 220

A rigorous introduction to the basic principles and concepts of modern microbiology. This course is recommended for students in the biological sciences and agricultural sciences curricula and for all students who plan to take further courses in microbiology. Credit will not be granted for both MB 301 and MB 401.

MB 405 (FS 405) FOOD MICROBIOLOGY 3(2 3) F
(See food science, page 158.)

FOR GRADUATES AND ADVANCED UNDERGRADUATES

MB 501 ADVANCED MICROBIOLOGY 4(3-2) F
Prerequisite: MB 401

A study in some depth of microbial structure and function, microbial ecology and characterization of important groups of microorganisms. Mr. Perry

MB 506 (FS 506) ADVANCED FOOD MICROBIOLOGY 3(1-6) S
(See food science, page 159.)

MB 514 MICROBIAL METABOLISM 4(3-2) S
Prerequisites: MB 401, BCH 351 or BCH 551

A study of the physiology and metabolism of microorganisms and their regulatory mechanisms. Mr. Dobrogosz

MB 521 MICROBIAL ECOLOGY 1(1-0) S
Prerequisite: Senior or graduate standing

A survey of the ecological role of microorganisms in our environment, their interaction with other living organisms and their function in biodegradation and recycling of organic matter in the ecosystem. Mr. Perry

MB 532 (SSC 532) SOIL MICROBIOLOGY 3(3-0) S
(See soil science, page 295.)

MB 551 IMMUNOLOGY AND SEROLOGY 2(1-2) S
Prerequisite: MB 401

A study of the basic concepts and principles of antibody production, antigen-antibody interaction, and the laboratory techniques for their demonstration and study. Mr. Lecce

MB 555 (ZO 555) PROTOZOOLOGY 4(2 6) S
(See zoology, page 334.)

MB 561 (BCH 561, GN 561) BIOCHEMICAL AND MICROBIAL GENETICS 3(3-0) F
(See biochemistry, page 74.)

MB 570 (BAE 570, CE 570) SANITARY MICROBIOLOGY 3(2 3) S
(See civil engineering, page 103.)

MB 571 VIROLOGY 3(3 0) S
Prerequisites: BCH 551, MB 401

An introduction to the fundamental aspects of virus-cell interactions. These include virus attachment and penetration, intracellular virus replication, metabolic changes occurring in cells as a result of virus infection and virus induced cellular transformations. Mr. Hayes

MB 574 (BO 574) PHYCOLOGY 3(1-4) S
(See botany, page 84.)

MB 575 (BO 575, PP 575) THE FUNGI 3(3-0) S
(See botany, page 84.

MB 576 (BO 576, PP 576) THE FUNGI LAB 1(0 3) S
(See botany, page 84.)

MB 590 TOPICAL PROBLEMS Credits Arranged FS
Prerequisite: Graduate standing, consent of instructor

Graduate Staff

FOR GRADUATES ONLY

MB 632 (SSC 632) ECOLOGY AND FUNCTIONS OF SOIL MICROORGANISMS 3(3-0) S
(See soil science, page 296.)

MB 690 MICROBIOLOGY SEMINAR 1(1 0) FS

Graduate Staff

MB 692 SPECIAL PROBLEMS IN MICROBIOLOGY Credits Arranged FS

Graduate Staff

MB 699 MICROBIOLOGY RESEARCH — Credits Arranged FS
Graduate Staff

Modern Languages

GRADUATE FACULTY

Professor GEORGE W. POLAND, *Head*
Professor: EDWARD M. STACK; *Associate Professors:* MARY PASCHAL, HARRY TUCKER, JR.; *Assistant Professor:* ERNEST W. ROLLINS

The Department of Modern Languages offers courses to assist graduate students in preparing themselves to use modern foreign languages in research and advanced study. Students are encouraged particularly to seek useful foreign research related to their thesis or other research in progress.

Certification may be obtained in languages not normally taught by the department with special permission of the Graduate School.

*MLF 401 FRENCH GRAMMAR FOR GRADUATE STUDENTS 3(3-0) F

This course is designed to present the grammar of scientific French as rapidly as possible in preparation for the reading course which follows.

*MLF 402 SCIENTIFIC FRENCH 3(3-0) S
Prerequisite: MLF 401 or equivalent

Reading and translation of technical French, supplemented by discussion on terminology, word order, vocabulary analysis and other linguistic techniques. Subject material adjusted to individual needs; conferences.

*MLG 401 GERMAN GRAMMAR FOR GRADUATE STUDENTS 3(3-0) F

This course is designed to present the grammar of scientific German as rapidly as possible in preparation for the reading course which follows.

*MLG 402 SCIENTIFIC GERMAN 3(3-0) S
Prerequisite: MLG 401 or equivalent

Reading and translation of technical German, supplemented by discussion of terminology, word order, vocabulary analysis and other linguistic techniques. Subject material adjusted to individual needs; conferences.

*MLS 401 SPANISH GRAMMAR FOR GRADUATE STUDENTS 3(3-0) F

This course is designed to present the grammar of scientific Spanish as rapidly as possible in preparation for the reading course which follows.

*MLS 402 SCIENTIFIC SPANISH 3(3-0) S
Prerequisite: MLS 401 or equivalent

Reading and translation of technical Spanish, supplemented by discussions on terminology, word order, vocabulary analysis and other linguistic techniques. Subject material adjusted to individual needs; conferences.

*These courses do not carry graduate language credit except with permission of the modern language department.

Nuclear Engineering

GRADUATE FACULTY

Professor RAYMOND L. MURRAY, *Head*
Professors: THOMAS S. ELLEMAN, *Graduate Administrator*, ROBIN P. GARDNER, RAYMOND F. SAXE, LLOYD R. ZUMWALT; *Associate Professors:* JAMES R. BOHANNON, JR., CHARLES E. SIEWERT, KURUVILLA VERGHESE; *Assistant Professor:* EPHRAIM STAM

The Department of Nuclear Engineering offers graduate study leading to the Master of Science and Doctor of Philosophy degrees.

Courses and research are available within the department and cooperating departments in several areas of nuclear engineering, including reactor theory and analysis, radiation detection, nuclear materials, radiation effects, energy transfer and conversion, nuclear safety and instrumentation, and radiation applications.

Among the available research facilities are a one-megawatt steady-state and pulse type research reactor (PULSTAR), a 50,000 curie Cobalt-60 gamma irradiation source, multichannel analyzers, IBM System 370, Model 165 computer, and a 1-MeV pulsed van de Graaff accelerator. Laboratories and reactor are housed in a new 50,000 square foot teaching and research building on the NCSU campus.

Candidates for admission are expected to hold the bachelor's degree in one of the fields of engineering or the physical sciences. Experience in nuclear physics, advanced differential equations and basic reactor theory will reduce the time required for completion of the degree. Courses in these areas can be included in the initial phases of the graduate program. Thirty semester hours (including four for research) and a thesis are required for the Master of Science degree. Well-qualified students may study directly toward the Doctor of Philosophy degree. Interdisciplinary research programs may be arranged for graduate students in cooperation with departments in the Schools of Engineering, Physical and Mathematical Sciences and Agriculture and Life Sciences.

Graduates of the department find positions in industry, government and academic institutions. The recent advent of competitive nuclear electric power has created a demand for nuclear engineers to participate in all phases of nuclear power plant design and operation. Opportunities include analysis, design, utilization and operation of nuclear facilities and radioisotopes applications.

FOR ADVANCED UNDERGRADUATES

NE 401 REACTOR ANALYSIS AND DESIGN 4(3-2) F
Corequisite: NE 302 or NE 419

The principles of neutron motion in matter, with emphasis on the analysis of the nuclear chain reaction. Slowing of neutrons, diffusion, space distribution of flux, conditions for criticality, group theories and the time-dependent behavior of fissionable assemblies. Laboratories include experiments on the motion and detection of neutrons and gamma rays, and detection of reactor radiations.

Mr. Verghese

NE 402 REACTOR ENGINEERING 4(3-2) S
Prerequisite: NE 401

A continuation of NE 401. Topics include heterogeneous reactor, temperature effects, instrumentation and control, thermal-hydraulic design, shielding and radiological safety. Considers reactor as part of an overall system and deals with system optimization and design. Laboratories include reactor start-up and control, reactor kinetics, reactor heat transfer and the monitoring of radioactivity in reactor effluents. Mr. Stam

NE 403 NUCLEAR ENGINEERING DESIGN PROJECTS 2(1-3) S
Prerequisite: NE 402

Student projects in design of practical nuclear engineering systems. The faculty of the nuclear engineering department participates in selection and direction of these projects. The use of computer codes is stressed. Staff

NE 419 INTRODUCTION TO NUCLEAR ENGINEERING 3(3 0) FS
Prerequisite: PY 206 or PY 208

A survey of nuclear energy applications, including nuclear reactor materials, reactor theory, shielding, thermal and hydraulic analysis, and control. Uses of nuclear fission and its byproducts in research, industry and propulsion are reviewed. The major engineering problems are defined and methods of approach are outlined. The course is intended to serve as an introduction to nuclear principles for engineers with no prior contact with the nuclear field. Mr. Stam

NE 491, 492 NUCLEAR ENGINEERING TOPICS I AND II 3(3-0) S
Prerequisite: NE 402

Typical offerings include:

NE 491A RADIATION APPLICATIONS

Radioisotope and radiation applications with emphasis on industrial utilization. Topics include: tracing techniques, gauging, radiography and radiation processing. Mr. Gardner

NE 491B NUCLEAR FUEL CYCLES AND ISOTOPE PRODUCTION

Consideration of the reactor fuel cycle from mining of the ore through fuel reprocessing. Includes fuel cycles, fuel element handling, isotope separation and isotope production. Mr. Verghese

NE 492A REACTOR SYSTEMS

Engineering topics pertinent to the design and operation of reactors are stressed. These include heat transfer in flowing fluids, power-plant systems, economics and reactor operations. Mr. Saxe

NE 492B RADIOLOGICAL AND REACTOR SAFETY

Radiation effects in biological materials, dose calculations, shielding, regulatory procedures and reactor safety systems are discussed. Emphasis is placed on safety procedures in conjunction with radioisotope sources and reactors. Mr. Elleman

FOR GRADUATES AND ADVANCED UNDERGRADUATES

NE 501 REACTOR ANALYSIS 3(3-0) F
Prerequisite: NE 302, NE 419 or consent of instructor

Provides a background on the principles of neutron motion in matter with

emphasis on the analysis of the nuclear chain reactor. A discussion of neutron mechanics, flux distributions, critical mass calculations, time behavior, two group models, and reactivity calculation is presented for the fission reactor. Mr. Siewert

NE 502 REACTOR DESIGN 3(3-0) S
Prerequisite: NE 501

Elements of nuclear reactor design and operation, including reactor materials, thermal and hydraulic analysis, control and safety, and thermal and fast reactor systems. Mr. Saxe

NE 504 (MA 504) MATHEMATICAL METHODS IN ENGINEERING 3(3-0) F
Prerequisite: MA 301 or 312

Survey of mathematical methods for engineers. Topics include ordinary dif ferential equations, matrices, partial differential equations, difference equations, numerical methods, elements of statistics. Techniques and applications to engi neering are stressed.

NE 505 EXPERIMENTAL METHODS IN NUCLEAR ENGINEERING 3(1 4) S
Prerequisites: NE 501 and NE(PY) 511
Corequisites: NE 502 and NE 512

Laboratory experiments are performed to illustrate the principles and concepts covered in NE 501, NE 502, NE 511 and NE 512. Mr. Gardner

NE 511 (PY 511) NUCLEAR PHYSICS FOR ENGINEERS 3(3-0) F
Prerequisite: PY 410

A study of the properties of atomic nuclei, of nuclear radiations and of the inter action of nuclear radiation with matter. Emphasis is placed on the principles of modern equipment and techniques of nuclear measurement and their application to practical problems. Mr. Waltner

NE 512 RADIATION APPLICATIONS 3(3-0) S
Prerequisite: NE 511 (PY 511)

Applications of radiation interaction principles to practical nuclear problems. Topics include radiological safety, effects of radiation on biological and structural materials, and industrial applications of radioisotopes and radiation. Mr. Elleman

NE 562 (MAT 562) MATERIALS PROBLEMS IN NUCLEAR ENGINEERING 3(3-0) F
Prerequisite: PY 410 or consent of instructor

Reactor component design considerations determined by materials properties as well as by nuclear function are covered. Emphasis is placed on radiation effects and other concepts pertinent to the selection of materials for nuclear reactors for either terrestrial or space applications. Mr. Fahmy

NE 573 (MAT 573) COMPUTER EXPERIMENTS IN MATERIALS ENGINEERING 3(3-0) F
Prerequisites: PY 407, MA 301

The basic techniques for constructing both statistical (Monte Carlo) and deterministic computer experiments will be explained and discussed from the standpoint of immediate use in the solution of current engineering research and development problems.

NE 591, 592 SPECIAL TOPICS IN NUCLEAR ENGINEERING I, II 3(3-0) FS
Prerequisite: Permission of instructor Staff

FOR GRADUATES ONLY

NE 601 REACTOR THEORY AND ANALYSIS 3(3-0) F
Prerequisite: NE 501

Theoretical aspects of neutron diffusion and transport related to the design computation and performance analysis of nuclear reactors. Principal topics are a unified view of the neutron cycle including slowing, resonance capture and thermalization; reactor dynamics and control; fuel cycle studies; and neutron transport methods. Background is provided for research in power and test reactor analysis. Mr. Murray

NE 602 ADVANCED REACTOR THEORY 3(3 0) S
Prerequisite: NE 601

A complete presentation of the singular eigenfunction expansion technique as applied in neutron transport theory for the analysis of nuclear reactors and to radiative heat transfer problems for participating media. Mr. Siewert

NE 611 RADIATION DETECTION 3(2-2) F
Prerequisite: NE 512

Covers the advanced aspects of radiation detection such as computer methods applied to gamma-ray spectroscopy, absolute detector efficiencies by experimental and Monte Carlo techniques, the use and theory of solid state detectors, time-of-flight detection experiments, and Mossbauer and other resonance phenomena.
Mr. Gardner

NE 620 NUCLEAR RADIATION ATTENUATION 3(3-0) F
Prerequisite: NE 502

The physical theory and mathematical analysis of the penetration of neutrons, gamma-rays and charged particles. Analytical techniques include point kernels, transport theory, Monte Carlo and numerical methods. Digital computers are employed in the solution of practical problems. Staff

NE 621 RADIATION EFFECTS ON MATERIALS 3(3-0) F
Prerequisite: NE 512

Interactions of radiation with matter, with emphasis on the physical effects. Current theories and experimental techniques are discussed. Annealing of defects, radiation induced changes in physical properties, and effects in reactor materials are discussed. Mr. Elleman

NE 622 TRANSPORT OF MATTER IN NUCLEAR REACTORS 3(3-0) S
Prerequisite: NE 512

Mechanisms of fission product migration in reactor solids and fluids. Emphasis is on absorption phenomena, thermodynamics of reversible processes, diffusion mathematics and experimental methods. Mr. Zumwalt

NE 631 REACTOR KINETICS AND CONTROL 3(3 0) S
Prerequisite: NE 501

A study of the control of nuclear reactor systems. Basic control theory is developed including the use of Bode, Nyquist, and S-plane diagrams, and state-variable methods. Reactor and reactor systems are analyzed by these methods and control methods and optimum-control methods are developed. Models for reactors and reactor-associated units, such as heat exchangers, are discussed. The effects of non-linearities are presented. Mr. Saxe

NE 641 RADIOISOTOPE APPLICATIONS 3(3-0) S
Prerequisite: NE 511 (PY 511)

Principles and techniques of radioisotope applications are presented. Topics

include radiotracer principles, radiotracer applications to engineering processes, radioisotope gauging principles and charged particle, gamma ray and neutron radioisotope gauges. Mr. Gardner

NE 653 NUCLEAR REACTOR DESIGN 3(3-0) F
Prerequisite: NE 601

A comprehensive analysis and design of a nuclear system or facility suggested and advised on by department faculty will be performed. The class is organized under the project engineering scheme, with work taking the form of feasibility study, and conceptual, preliminary or parametric analysis and design. Interdisciplinary topics such as siting, safety analysis, shielding, engineered safeguards, economics, material selection and project management are key parts of the course. Results are reviewed by an interdepartmental board. Mr. Bohannon

NE 691, 692 ADVANCED TOPICS IN NUCLEAR ENGINEERING I, II 3(3-0) FS
Prerequisite: Consent of instructor

A study of recent developments in nuclear engineering theory and practice. Staff

NE 695 SEMINAR IN NUCLEAR ENGINEERING 1(1 0) FS

Discussion of selected topics in nuclear engineering. Staff

NE 699 RESEARCH IN NUCLEAR ENGINEERING Credits Arranged
Prerequisite: Graduate standing

Individual research in the field of nuclear engineering. Staff

Nutrition

GRADUATE FACULTY

Professors: LEONARD W. AURAND, ELLIOTT R. BARRICK, ALBERT J. CLAWSON, ELOISE S. COFER, WILLIAM E. DONALDSON, CHARLES H. HILL, JAMES M. LEATHERWOOD, JAMES G. LECCE, H. L. LUCAS, GENNARD MATRONE, HAROLD A. RAMSEY, HOWARD A. SCHNEIDER, FRANK H. SMITH, SAMUEL B. TOVE, GEORGE H. WISE; *Associate Professors:* EVAN E. JONES, JOHN J. MCNEILL, RICHARD D. MOCHRIE, ALLEN H. RAKES; *Assistant Professor:* JIM D. GARLICH

Graduate study leading to a Master of Nutrition, Master of Science or Doctor of Philosophy degree may be taken under the direction of any of the graduate faculty for the nutrition program. This program is interdepartmental, and the student may reside and conduct research in any of the following departments which participate in the program: animal science, poultry science, food science or biochemistry. The student will ordinarily reside in the department of his major adviser. The program involves various species of animals and therefore the comparative approach to nutrition is emphasized.

Majors in the program may minor in biochemistry, physiology, microbiology, statistics or other approved fields.

Research facilities in each of the departments are extensive and the problems under investigation are many and varied.

This program is administered by the Nutrition Advisory Committee through its executive committee comprising the committee chairman and one member from each participating department. Additional information about the program may be obtained by writing to any one of the above graduate faculty members or to the Chairman, Nutrition Program, P. O. Box 5306, School of Agriculture and Life Sciences, N. C. State University, Raleigh, North Carolina 27607.

FOR ADVANCED UNDERGRADUATES

NTR 415 (ANS 415, PO 415) COMPARATIVE NUTRITION 3(3-0) F
Prerequisite: CH 220 or CH 221

Fundamentals of animal nutrition, including classification of nutrients, their requirement and general metabolism by different species for health, maintenance, growth and other productive functions. Messrs. Donaldson, Ramsey

NTR 590 TOPICAL PROBLEMS IN NUTRITION Maximum 6 FS
Prerequisite: Graduate or senior standing

Analysis of problems of current interest in nutrition. Credit for this course will involve the scientific appraisal and solution of a selected problem. The problems will be designed to provide training and experience in research. Graduate Staff

FOR GRADUATES ONLY

NTR 601 AMINO ACIDS, VITAMINS, AND MINERALS IN NUTRITION 4(4-0) S
Prerequisites: BCH 551, ZO 421, and a 400-level nutrition course

This course is designed to give the student knowledge in depth of the nutritional biochemistry of amino acids, vitamins and minerals. Nutritional principles are presented and interpreted from the viewpoint of metabolic pathways and biochemical reaction mechanisms. Mr. Garlich

NTR 608 ENERGY METABOLISM 3(3-0) F
Prerequisites: BCH 551 and a 400 level nutrition course

The course relates biochemical and physiological events within the cell, tissue, organ and system with the nutrient needs as sources of energy for productive animal life. Digestion, absorption and metabolism of carbohydrates under normal and pathological states will be discussed. Processes of energy transformations within living structures will be presented in relation to free energy, biological oxidations, coupled reactions, anabolic and catabolic systems, hormonal effects, metabolic control and efficiency. Mr. Leatherwood

NTR 690 ADVANCED SPECIAL PROBLEMS IN NUTRITION Maximum 6 FS
Prerequisite: Graduate standing

Directed research in a specialized phase of nutrition designed to provide experience in research methodology and philosophy. Graduate Staff

NTR 699 RESEARCH IN NUTRITION Credits by Arrangement FS
Prerequisite: Graduate standing. Maximum 6

Original research preparatory to the thesis for the Master of Science or Doctor of Philosophy degree.

Operations Research

OPERATIONS RESEARCH COMMITTEE

Professor SALAH E. ELMAGHRABY, *Chairman*
Professors: JOHN F. BOGDAN, N. W. CONNER, *ex officio*, WALTER J. PETERSON, *ex officio*, N. J. ROSE; *Adjunct Professor:* JAY T. WAKELEY; *Associate Professors:* NORMAN R. BELL, BIBHUTI B. BHATTACHARYYA, WILLIAM S. GALLER, WILLIAM L. HAFLEY, DAVID A. LINK, CLARENCE J. MADAY; *Assistant Professors:* RICHARD M. FELDER, HENRY L. W. NUTTLE, RICHARD K. PERRIN

ASSOCIATED GRADUATE FACULTY

Professors: WILLIAM J. BARCLAY, JOHN W. BISHIR, ARTHUR R. ECKELS, SALAH E. ELMAGHRABY, ARNOLD H. E. GRANDAGE, ROBERT J. HADER, ROBERT W. LLEWELLYN, ROBERT J. MONROE, BERNARD M. OLSEN, CHARLES H. PROCTOR, HANS SAGAN, JAMES A. SEAGRAVES, HUBERTUS R. VAN DER VAART, OSCAR WESLER; *Visiting Professor:* MAKOTO ITOH; *Associate Professors:* RAUL E. ALVAREZ, NORMAN R. BELL, RICHARD BERNHARD, BIBHUTI B. BHATTACHARYYA, RICHARD E. CHANDLER, WILLIAM L. HAFLEY, CLEON W. HARRELL, JR., DAVID A. LINK, CLARENCE J. MADAY, DONALD C. MARTIN, WILBUR C. PETERSON, EDWARD H. WISER; *Assistant Professors:* GERALD E. BENNINGTON, W. DOUGLAS COOPER, RICHARD M. FELDER, MICHAEL J. MAGAZINE, HENRY L. W. NUTTLE, RICHARD K. PERRIN

Operations research is a graduate program of a multidisciplinary nature, governed by the Operations Research Committee and administered through the office of the chairman of the committee. The committee has representatives from the Departments of Chemical Engineering, Civil Engineering, Computer Science, Economics, Electrical Engineering, Engineering Mechanics, Industrial Engineering, Mathematics, Statistics, School of Forest Resources and the School of Textiles.

The program offers graduate studies leading to the degree of Master of Science and Doctor of Philosophy. Both degrees require a thesis; a foreign language is not required at the master's level but is required at the doctorate level. Students admitted to the Graduate School to pursue studies in operations research are expected to have a strong background in mathematics, statistics and the physical sciences, including operational mathematics and matrices. Those students who do not have these courses will be required to take them in addition to the other graduate courses comprising their programs of study.

A meaningful program of study in operations research usually implies intensive study and proficiency in at least two of the following areas of knowledge:

Mathematical Theories of Optimization
Control Systems, Cybernetics and Reliability
Stochastic Systems
Econometrics and Economic Decision Theory
Information and Computer Sciences

While each individual student's plan of study would be specifically tailored to meet his own personal desires and professional needs, the student's committee will be guided by the spirit of the need to compose a coherent program that enhances excellence in practice and research.

Because of the many-faceted nature of operations research and its applicability to a wide range of fields of study, the Operations Research Committee has also established a strong graduate minor program in operations research, with the major in any basic discipline which could contribute to, or utilize, operations research. It is recognized, as has been recognized by many other universities, that research in some major fields, such as industrial engineering or statistics may be construed as research in operations research. This recognition has been reflected in the flexibility awarded to the design of the course of study of any student. If a student majors in a discipline which demands a high level of proficiency in one (or more) of the five areas of knowledge listed above, he would be expected to take courses from this area (or areas) as part of the major and select the operations research courses from other areas. In this case, the student's committee is guided by the spirit of the need to complement his knowledge and to broaden his scope. The cohesive elements in the Operations Research Program are to be the introductory survey of Operations Research (OR 501) and the Seminar (OR 695).

The courses in operations research have been organized into "central" and "cognate" courses. The "central" courses represent the core of the body of knowl edge which has come to be associated with OR. The "cognate" courses are intended to assist the graduate student and his advisory committee in charting his program for optimal self development and specialized education.

ADMISSION

Prospective graduate students should contact the Dean of the Graduate School for application for admission forms and for a copy of the graduate catalog.

General information regarding the Operations Research Program can be obtained from:

Dr. Salah E. Elmaghraby, Director
Operations Research Program
P. O. Box 5511
Raleigh, North Carolina 27607

Both teaching and research assistantships are available to qualified applicants each year from the departments and schools represented on the Operations Research Committee. Requests for such assistance should be directed to these departments and schools or to the director of the OR Program.

The OR Committee at the Raleigh campus and the Operations and Systems Analysis Committee at Chapel Hill maintain strong ties of liaison and cooperation. The two programs are, in many instances, complementary to each other and the prospective student is encouraged to consider course offerings at both campuses in structuring his program of study. An abbreviated list of the course offerings at Chapel Hill campus is included for ease of reference.

OR 501 INTRODUCTION TO OPERATIONS RESEARCH 3(3-0) F Sum.
Prerequisites: MA 405, MA 421; required all OR students

OR Approach: modeling, constraints, objective and criterion. The problem of Multiple criteria. Optimization, Model validation. The team approach. Systems Design. Examples, OR Methodology: mathematical programming; optimum seeking; simulation, gaming; heuristic programming. Examples. OR Applications; theory of inventory; economic ordering under deterministic and stochastic demand. The production smoothing problem; linear and quadratic cost functions. Waiting line problems: single and multiple servers with Poisson input and output. The theory of games for two-person competitive situations. Project management through PERT-CPM. Messrs. Cooper, Bennington

OR 505 (IE 505, MA 505) MATHEMATICAL PROGRAMMING I 3(3 0) F Sum.
Prerequisite: MA 405

A study of mathematical methods applied to problems of planning. Linear programming will be covered in detail. This course is intended for those who desire to study this subject in depth and detail. It provides a rigorous and complete development of the theoretical and computational aspects of this technique as well as a discussion of a number of applications. Graduate Staff

OR 509 (IE 509) DYNAMIC PROGRAMMING 3(3-0) S Sum.
Prerequisites: MA 405, ST 421

An introduction to the theory and computational aspects of dynamic programming and its application to sequential decision problems. Messrs. Elmaghraby, Nuttle

OR 520 THEORY OF ACTIVITY NETWORKS 3(3 0) S
Prerequisites: OR 501, OR 505 (IE 505, MA 505)

Introduction to graph theory and network theory. A discussion in depth of the theory underlying (i) deterministic activity networks (CPM): optimal time cost trade offs; the problem of scarce resources; (ii) probabilistic activity networks (PERT): critical evaluation of the underlying assumptions; (iii) generalized activity networks (GERT, GAN): applications of signal flow graphs and semi-Markov process to probabilistic branching; relation to the theory of scheduling. (Offered in alternate years.) Mr. Elmaghraby

OR 522 (IE 522) DYNAMICS OF INDUSTRIAL SYSTEMS 3(3 0) F
Prerequisite: IE 421

A study of the dynamic properties of industrial systems; introduction to servo mechanism theory as applied to company operations. Simulation of large nonlinear, multiloop, stochastic systems on a digital computer; methods of determining modifications in systems design and/or operating parameters for improved system behavior. Mr. Llewellyn

OR 527 (CHE 527) OPTIMIZATION OF ENGINEERING PROCESSES 3(3-0) F
Prerequisites: MA 511, CSC 111

Mathematical methods for the optimization of engineering processes are developed, and illustrative applications of these methods are presented and discussed. Specific topics covered are drawn from a list which includes mathematical programming, geometric programming, sensitivity analysis, direct search and elimination techniques, variational techniques and the minimum principle, quasilinearization and dynamic programming. The emphasis throughout the course is on applications of the techniques discussed rather than fully rigorous development of the theory. Mr. Felder

OR 561 (IE 561) QUEUES AND STOCHASTIC SERVICE SYSTEMS 3(3-0) F
Prerequisite: MA 421

General concepts of stochastic processes are introduced. Poisson processes, Markov processes, and Renewal theory are presented. These are then used in the analysis of queues, starting with a completely memoryless queue to one with general parameters. Applications to many engineering problems will be considered. Mr. Magazine

OR 586 (IE 586) NETWORK FLOWS 3(3-0) S
Prerequisites: OR 505 (IE 505, MA 505)

This course will study problems of flows in networks. These problems will include the determination of the shortest chain, maximal flow and minimal cost flow in networks. The relationship between network flows and linear programming will be developed as well as problems with nonlinear cost functions, multi-commodity flows, and the problem of network synthesis. (Offered in alternate years.) Mr. Bennington

OR 606 (MA 606, ST 606) MATHEMATICAL PROGRAMMING II 3(3 0) S
Prerequisite: OR 505 (IE 505, MA 505)

This course is intended for those who desire to study linear and nonlinear programming from an advanced mathematical point of view. Special attention will be paid to the theoretical and computational aspects of current research problems in the field of linear and nonlinear programming, game theory, theory of graphs, discrete linear programming, linear programming, under uncertainty and dynamic programming. Messrs. Bhattacharyya, Magazine

OR 609 ADVANCED DYNAMIC PROGRAMMING 3(3-0) F
Prerequisites: OR 509, MA 541

Introduction to measure theoretic concepts, review of finite state Markov proc esses, theory of Markovian programming, discrete decision processes, continuous time dynamic programming, relation to Calculus of Variation and the Maximum Principle. Emphasis throughout is on recent theoretical development in the field. (Offered in alternate years.) Mr. Elmaghraby

OR 631, 632 (EM 631, 632) VARIATIONAL METHODS IN OPTIMIZATION TECHNIQUES I, II 3(3-0) FS
Prerequisites: (631) MA 511, MA 512; (632) OR 631

Variational methods are applied to optimization problems in engineering, where examples are drawn from flight mechanics, operations research, heat transfer, structures and aerodynamics. The necessary conditions which follow from the general variation of a functional are developed. Solutions with corners and discontinuities are considered. Inequality constraints on control variables and constrained extreme are also considered. Gradient methods are described. Applications in operations research are made for problems with continuous function representation such as might be found in production scheduling, inventory control and process control. Mr. Maday

OR 691 SPECIAL TOPICS IN OPERATIONS RESEARCH 3(3-0) FS Sum.
Prerequisites: OR 501, OR 505 (IE 505, MA 505)

The purpose of this course is to allow individual students or small groups of students to take on studies of special areas in OR which fit into their particular program and which may not be covered by other OR courses. The work will be directed by a qualified faculty member and in some instances by visiting professors. The subject matter in any year is dependent on the students and the faculty members. Graduate Staff

OR 692 (IE 692, MA 692) SPECIAL TOPICS IN MATHEMATICAL PROGRAMMING 3(3-0) FS Sum.
Prerequisite: OR 505 (IE 505, MA 505)

The study of special advanced topics in the area of mathematical programming. New techniques and current research in this area will be discussed. The faculty responsible for this course will select the areas to be covered during the semester according to their preference and interest. This course will not necessarily be taught by an individual faculty but can, on occasion, be a joint effort of several faculty members from this University as well as visiting faculty from other institutions. To date, a course on Theory of Networks and another on Integer Programming have been offered under the umbrella of this course. It is anticipated that these two topics will be repeated in the future, together with other topics. Graduate Staff

OR 695 SEMINAR IN OPERATIONS RESEARCH 1(1 0) FS
Prerequisite: Enrollment in operations research as major or minor

Seminar discussion of operations research problems. Case analyses and reports. Graduate students with minors or majors in operations research are expected to attend throughout the period of their residence. Graduate Staff

OR 699 PROJECT IN OPERATIONS RESEARCH 1-3 FS Sum.
Prerequisites: Variable

Individual research by graduate students minoring and majoring in operations research. Research may be done under the operations research faculty member meeting the interest need of the student. Graduate Staff

SUGGESTED COGNATE COURSES

Civil Engineering

CE 575 Civil Engineering

Economics

EC 550 Mathematical Models in Economics
EC 650 Economic Decision Theory
EC 651 (ST 651) Econometrics
EC 652 (ST 652) Topics in Econometrics

Electrical Engineering

EE 506 Dynamical Systems Analysis
EE 516 Feedback Control Systems
EE 520 Fundamentals of Logic Systems
EE 521 Digital Computer Technology and Design
EE 613, 614 Advanced Feedback Control
EE 642 Automata and Adaptive Systems
EE 651 Statistical Communication Theory

Industrial Engineering

IE 521 Control Systems and Data Processing
IE 523 Inventory Control Methods I
IE 547 Engineering Reliability
IE 608 Linear Programming Applications
IE 611 The Design of Production Systems
IE 622 Inventory Control Method II

Mathematics

MA 521 A Survey of Modern Algebra
MA 536 Logic for Digital Computers
MA 537 Mathematical Theory of Digital Computers
MA 541, 542 (ST 541, 542) Theory of Probability I & II
MA 617, 618 (ST 617, 618) Measure Theory and Advanced Probability
MA 619 (ST 619) Topics in Advanced Probability
MA 622 Linear Algebra
MA 641, 642 Calculus of Variations and Theory of Optimal Control I & II

Statistics

ST 613, 614 Time Series Analysis I & II
ST 691C Advanced Special Problems; Theory of Stochastic Processes (a one year course)

Textiles

TX 591 Special Topics

COGNATE COURSES AT CHAPEL HILL

The following is a cross-listing of the courses offered at the University of North Carolina at Chapel Hill which are designated as related to operations research.

Business

205 Dynamic Programming
206 Decision Theory

208 Simulation Theory
226 Linear Programming
227 Mathematical Programming I
304 Control and Optimization
309 Inventory Theory

City and Regional Planning

127 Transportation Seminar
228 Metropolitan Analysis
232 Public Investment Theory
234 Planning of Water Resource Systems
265 Social Policy Planning and Analysis
284 Systems Analysis in Environmental Planning

Computer and Information Science

118 Information Systems for Statistical Problems
120 Fundamentals of Information Processing
135 Data Processing and File Management
150 (or 151-152) Numerical Methods in Applied Mathematics

Economics

182, 183 Mathematical Economics
200, 201 Advanced Microeconomic Theory
273, 274 Advanced Econometrics

Environmental Sciences and Engineering

226 Ecology and General Systems Theory

Mathematics

134 (or 136-137) Algebra
163 Elementary Topology I
173, 174 Topics in Applied Mathematics
193, 194 Analysis

Statistics

127 Mathematical Statistics
129 Introduction to Stochastic Processes
133, 237 Time Series Analysis
156, 158 Combinatorial Mathematics and Graph Theory
180, 181 Mathematical Methods of Operations Research I & II

Physical Oceanography

(For a listing of graduate faculty and departmental information, see geosciences page 171.)

FOR ADVANCED UNDERGRADUATES

OY 487 (CE 487, MAS 487) Physical Oceanography 3(3-0) S
Prerequisites: MA 202, PY 212

An introduction, on an advanced level, to the principles of physical oceanography. Subjects to be covered are: history of physical oceanography; the geological and

astronomical background for the field; tides and waves; fluid mechanics; characteristics of sea water; advective and convective processes; current measurements; laboratory models; and specific problems in physical oceanography.

FOR GRADUATES AND ADVANCED UNDERGRADUATES

OY 541 (MAS 541, CE 541) GRAVITY WAVE THEORY I 3(3-0) S
Prerequisite: EM 303 or PY 411

Classical gravity wave theory with emphasis on the basic mechanics of wave motions, mass transport induced by waves and various conservation laws with their applications in wave study. Mr. Huang

OY 551 (MAS 551) OCEAN CIRCULATION 3(3 0) S
Prerequisite: EM 303 or PY 411

Basic study of the mechanics of ocean circulation with emphasis on various simple models of circulation systems. Mr. Huang

FOR GRADUATES ONLY

OY 601, 602 (MAS 601, 602) ADVANCED PHYSICAL OCEANOGRAPHY I, II 3(3 0) FS
Prerequisite: OY 487 (MAS 487, CE 487)

An in depth discussion of physical oceanography both geographic and hydro dynamical aspects. Topics discussed include relief of ocean floor; physical properties of sea water; distribution of temperature, salinity and currents; and kinematical and dynamical studies of motion of sea water turbulence. Mr. Knowles

OY 605, 606 (MAS 605, 606; EM 605, 606) ADVANCED GEOPHYSICAL FLUID MECHANICS I, II 3(3 0) FS
Prerequisite: EM 504, 505 or equivalent

An application of basic fluid mechanics principles in geophysical fluid mechanics studies with emphasis on the most important physical parameters encountered in the field of geophysical fluid mechanics, such as: mechanics of stratified fluids, rotating fluids, stratified and rotating fluid, stability and turbulence in ocean and atmosphere. (Offered 1972-73 and alternate years.) Mr. Huang

OY 613, 614 (MAS 613, 614; EM 613, 614) PERTURBATION METHOD IN FLUID MECHANICS I, II 3(3 0) FS
Prerequisites: MA 401, EM 303

Basic theory and application of perturbation methods in fluid mechanics including: regular and singular perturbations, matching principles, method of strained coordinate, two variable expansion and applications to partial differential equations. (Offered 1973-74 and alternate years.) Mr. Huang

OY 699 RESEARCH Credits Arranged FS
Prerequisites: Graduate standing and consent of advisory committee

Graduate research in fulfillment of requirements for a graduate degree.
Graduate Staff

Physics

GRADUATE FACULTY

Professor Lewis W. Seagondollar, *Head*

Professors: Willard H. Bennett, John M. A. Danby, William R. Davis, Wesley O. Doggett, George L. Hall, Alvin W. Jenkins, Jr., Harry C. Kelly, Joseph T. Lynn, *Graduate Administrator*, Edward R. Manring, Jasper D. Memory, Arthur C. Menius, Jr., Raymond L. Murray, Don L. Ridgeway, Arthur W. Waltner; *Visiting University Professor;* Llewellyn H. Thomas; *Professors Emeritus:* Forrest W. Lancaster, Jefferson S. Mears, Rufus H. Snyder; *Associate Professors:* Grover C. Cobb, Jr., Gerald H. Katzin, David H. Martin, Gary E. Mitchell, Marvin K. Moss, Jae Y. Park, Richard R. Patty, David R. Tilley; *Assistant Professors:* Kwong T. Chung, Raymond E. Fornes, Christopher R. Gould, Fred Lado, Jr., George W. Parker, III, Jan F. Schetzina

Study in physics is available leading to the degrees Master of Science and Doctor of Philosophy. In addition to the areas of research listed below, thesis work may also be done in closely related departments in the fields of biophysics, environmental sciences, nuclear reactor theory and computer science. There are available to the department the computer facilities (including the IBM System 360/75 computer) of the nearby Triangle Universities Computation Center which is jointly operated by Duke University, the University of North Carolina at Chapel Hill and N. C. State University.

Programs of study leading to the Master of Science degree require a minimum of 30 semester hours, including four credits of research and two of seminar. In addition, a thesis is required.

The Doctor of Philosophy degree is granted on successful completion of examinations, independent research and the submission of an acceptable dissertation. A minor area of study is required, mathematics usually being elected.

All graduate students and staff are expected to attend a weekly colloquium at which topics of current interest in physics are discussed.

The Department of Physics participates in a number of national fellowship programs such as those of the National Defense Education Act. In addition, many teaching and research assistantships are available. Depending upon the student's experience, these pay from $2,900 to $3,800 for half-time duties during the nine month school year. A student holding such a half time assistantship may carry 60 percent of a full course load.

Staff and facilities are available for special study and research at both the master's and doctoral levels in the areas listed below. In most of these areas the work is supported by grants or contracts, and research assistantships are available.

ATMOSPHERIC PHYSICS

Measurements are being made on synthetic atmospheres prepared in the laboratory, as well as on the earth's atmosphere from an observing site remote from city light.

ATOMIC AND MOLECULAR PHYSICS

Collision probabilities are being studied both theoretically and experimentally for low energy ion-atom interactions. Also, the study of two-component diffusion of

neutral gas molecules is being applied to vapor removal processes at low densities.

MAGNETIC RESONANCE

Research programs in both high resolution and broad line NMR spectroscopy are in progress, using a Varian HA-100 high resolution spectrometer and a Varian DA-60 dual purpose spectrometer. The spectra are analyzed by computer, and the results compared with theoretical calculations of the relevant parameters.

NUCLEAR PHYSICS

Duke University, North Carolina State University and the University of North Carolina at Chapel Hill jointly staff the Triangle Universities Nuclear Laboratory located on the Duke campus. The major facilities are a 15 MeV Model FN Tandem Van de Graaff accelerator with a 15 MeV cyclotron injector and on-line computer facilities.

PLASMA PHYSICS

The plasma research program is investigating various aspects of the behavior of charged particle beams. The laboratory is supported by well-equipped machine shops and tube-making facilities which are staffed with skilled technicians. Off campus facilities include a 10 MeV pulsed X ray machine and auxiliary equipment.

SEMICONDUCTOR PHYSICS

Electrical properties of semiconductors are being studied.

THEORETICAL PHYSICS

The theoretical work in the department is in six main areas.

Atmospheric Physics—The area of primary interest is that of the electromagnetic properties of the upper atmosphere.

Atomic Physics A study of electron atom collision theory and of the interaction of the electromagnetic field with atomic systems is under way.

Nuclear Physics—The principal area of research is the study of direct nuclear reaction theories.

Relativistic Theory of Particles and Fields An attempt is being made to develop a Hamiltonian theory of the interaction of particles and fields without introducing unobservable variables.

Relativity and General Field Theory The problems encountered in the formulation of the differential and integral conservation laws of the general theory of relativity, and general field theories are under investigation. In a second area, the differential geometry of hypersurfaces embedded in Riemannian space-time together with the theory of mathematical deformation of manifolds is being applied to some problems concerning frames of reference in general relativity.

Statistical and Solid State Theory The areas being investigated include (a) the quantum theory of cooperative phenomena in solids; (b) the statistical description of the liquid state in which an attempt is made to extract the observable macroscopic properties of dense fluids from the microscopic laws; (c) the study of exact statistical mechanics, especially ergodic theory and the stochastic structure of statistical mechanics; (d) the theory of dipolar-broadened NMR line widths in solids.

FOR ADVANCED UNDERGRADUATES

PY 401, 402 MODERN AND QUANTUM PHYSICS I, II 3(3-0) FS
Prerequisite: PY 411

An introductory treatment of the basic theories of modern physics, particularly relativity and quantum mechanics, together with application of these theories to the study of atomic structure, optical spectra, X-rays, nuclear physics, solid state physics and elementary particles.

PY 407 INTRODUCTION TO MODERN PHYSICS 3(3-0) FS
Prerequisites: MA 202, PY 208

A survey of the important developments in atomic and nuclear physics of this century. Among topics covered are: an introduction to special relativity, atomic and molecular structure, determination of properties of ions and fundamental particles, the origin of spectra, and nuclear reactions.

PY 409 ION AND ELECTRON PHYSICS 3(2-3) S
Prerequisite: PY 414

Topics covered include collision processes in gases, electron emission, charged particle dynamics, gaseous discharges, and the physics of electron and ion beams.

PY 410 NUCLEAR PHYSICS I 4(3-2) FS
Prerequisite: PY 207 or PY 407

An introduction to the properties of the nucleus, and the interaction of radiation with matter. A quantitative description is given of natural and artificial radioactivity, nuclear reactions, fission, fusion and the structure of simple nuclei.

PY 411, 412 MECHANICS I, II 3(3-0) FS
Prerequisites: MA 301, PY 207 or PY 208

A sequence of courses in intermediate theoretical mechanics, including the dynamics of particles and rigid bodies, gravitation and moving reference systems. An introduction is given to advanced mechanics, including Lagrangian and Hamiltonian dynamics.

PY 413 THERMAL PHYSICS 3(3-0) S
Prerequisite: PY 206 or PY 208
Corequisite: MA 301

An introduction to the statistical study of macroscopic systems. Topics covered include basic concepts of probability, the microscopic states of large systems, the concepts of temperature, heat and entropy, and the relations between these quantities.

PY 414, 415 ELECTRICITY AND MAGNETISM I, II 3(3-0) FS
Prerequisite: PY 207 or PY 208
Corequisite: MA 511

An intermediate course in the fundamentals of static and dynamic electricity and electromagnetic theory, developed from basic experimental laws. Vector methods are introduced and employed throughout the course.

PY 416 PHYSICAL OPTICS 3(2-2) F
Prerequisite: PY 415

An intermediate course in physical optics with the major emphasis on the wave properties of light. Subjects covered include boundary conditions, optics of thin films, interference and diffraction, with applications to absorption, scattering and laser operation.

PY 443 ASTROPHYSICS 3(3-0) S
Prerequisites: PY 207 or PY 407; PY 411

A survey of the basic physics necessary to investigate, from observational data, the internal conditions of stars and their evolution. Topics to be considered will include the formation and structure of spectral lines, methods of energy generation and transport, stellar structure, degeneracy and white dwarfs.

PY 451, 452 INTERMEDIATE EXPERIMENTS IN PHYSICS I, II 2(1-3) FS
Corequisites: PY 411, PY 414

Experiments at the intermediate level in mechanics, electricity and magnetism, and modern physics.

PY 499 SPECIAL PROBLEMS IN PHYSICS 1-3 FS
Prerequisite: Consent of department

Study and research in special topics of classical and modern physics. A topic may be chosen for experimental or theoretical investigation, or a literature survey may be made.

FOR GRADUATES AND ADVANCED UNDERGRADUATES

PY 501, 502 INTRODUCTION TO QUANTUM MECHANICS I, II 3(3 0) FS
Prerequisites: MA 511; PY 411 or PY 414

An introduction to the fundamental concepts and formulations of quantum mechanics, including its interpretation and techniques, and the application of the theory to simple physical systems, such as the free particle, the harmonic oscillator, the particle in a potential well and central force problems. Other topics include approximation methods, identical particles and spin, transformation theory, symmetries and invariance, and an introduction to quantum theory of scattering and angular momentum. Mr. Chung

PY 503, 504 INTRODUCTION TO THEORETICAL PHYSICS I, II 3(3-0) FS
Prerequisites: MA 511, PY 412, PY 414

An introductory course in theoretical physics which offers preparation for advanced graduate study. Emphasis is on classical mechanics, special relativity and the motion of charged particles. Topics covered include variational principles, Hamiltonian dynamics and the canonical transformation theory, structure of the Lorentz group and elementary dynamics of unquantized fields. Mr. Katzin

PY 507 ADVANCED ATOMIC PHYSICS 3(3-0) F
Prerequisites: MA 511, PY 412, PY 415

An introduction to the quantum mechanical treatment of atomic structure and spectra. Topics covered include the relativistic hydrogen atom, the helium atom, multielectron atoms, selection rules, etc. Mr. Chung

PY 509 PLASMA PHYSICS 3(3-0) F
Prerequisite: PY 414

A study of the individual and collective motion of charged particles in electric and magnetic fields and through ionized gases, including the pinch effect and induced processes in relativistic streams; transport equations; and properties of plasmas, including wave production and propagation, instabilities, shocks, and radiation losses, with applications. Mr. Bennett

PY 510 NUCLEAR PHYSICS II 4(3-2) F
Prerequisite: PY 410

A study of the properties of the atomic nucleus as revealed by radioactivity, nuclear reactions and scattering experiments, with emphasis on the experimental approach. The laboratory is designed to stimulate independent research and offers project work in nuclear spectroscopy and in neutron physics. Mr. Waltner

PY 511 (NE 511) NUCLEAR PHYSICS FOR ENGINEERS 3(3-0) F
Prerequisite: PY 410

A study of the properties of atomic nuclei, of nuclear radiations and of the interaction of nuclear radiation with matter. Emphasis is placed on the principles of modern equipment and techniques of nuclear measurement and their application to practical problems. Mr. Waltner

PY 514, 515 ADVANCED ELECTRICITY AND MAGNETISM I, II 3(3-0) FS
Prerequisite: PY 415

An advanced treatment of electricity and magnetism and electromagnetic theory. Topics include: techniques for the solution of potential problems, development of Maxwell's equations; wave equations; energy, force and momentum relations of an electromagnetic field; covariant formulation of electrodynamics; radiation from accelerated charges. Mr. Hall

PY 517 MOLECULAR SPECTRA 3(3 0) S
Prerequisites: PY 407, PY 412; PY 507 recommended

Topics include the interpretation of infrared and Raman spectra for diatomic and simple polyatomic molecules; the effects due to vibration-rotation interaction, electronic motion and nuclear spin; nuclear magnetic resonance spectroscopy; infrared absorption in the earth's atmosphere. Mr. Chung

PY 520 MEASUREMENTS IN NUCLEAR PHYSICS 3(2-2) S
Prerequisite: PY 410

A study of the fundamentals of statistics (including the binomial, normal, Poisson and interval distributions) as applied to the analysis of measurements on nuclear reactions and radioactivity. Mr. Waltner

PY 521 KINETIC THEORY OF GASES 3(3-0) F
Prerequisite: PY 413

A phenomenological and theoretical study of systems of dilute gases. After treatment of the continuum mechanics of fluids, the postulates of kinetic theory are presented and the derivation from them of macroscopic conservation equations, transport laws and thermodynamic properties is discussed. Mr. Ridgeway

PY 552 INTRODUCTION TO THE STRUCTURE OF SOLIDS 3(3-0) S
Prerequisite: PY 401

Basic considerations of crystalline solids, metals, conductors and semiconductors. Mr. Schetzina

PY 555 (MA 555) MATHEMATICAL INTRODUCTION TO CELESTIAL MECHANICS 3(3-0) F

(See mathematics, page 213).

PY 556 (MA 556) ORBITAL MECHANICS 3(3-0) F

(See mathematics, page 214.)

PY 599 SENIOR RESEARCH 3 FS
Prerequisite: Senior honors program standing, except with special permission

Investigations in physics under the guidance of staff members, which may consist of literature reviews, experimental measurements or theoretical studies.
Graduate Staff

FOR GRADUATES ONLY

PY 600 PLANETARY ATMOSPHERES 3(3-0) S
Prerequisite: PY 507

Gas dynamics of atmospheres with emphasis on recent results of rocket, satellite and interplanetary probes. Theories of the airglow, aurora and ionosphere are developed. Mr. Manring

PY 601, 602 THEORETICAL PHYSICS I, II 3(3-0) FS
Prerequisites: PY 503, PY 514
Corequisite: MA 661

The mathematical and theoretical approach to the relationships between various branches of physics is treated. The restricted theory of relativity, electrodynamics, classical field theory and the general theory of relativity and geometrodynamics are considered. Mr. Davis

PY 609 HIGH ENERGY PHYSICS 3(3-0) S
Prerequisite: PY 510

The experimental and theoretical aspects of nuclear processes at high energy are treated. Graduate Staff

PY 610 ADVANCED NUCLEAR PHYSICS 3(3-0) F
Prerequisite: PY 410
Corequisite: PY 501

A theoretical study of nuclear structure and reactions. Topics include the deuteron, low energy nucleon scattering, nuclear forces, nuclear moments, nuclear shell theory, collective model, compound nucleus, optical model and direct reaction theories. Mr. Park

PY 611 QUANTUM MECHANICS 3(3-0) F
Prerequisites: MA 512, PY 502

A treatment of nonrelativistic quantum mechanics at the advanced level, including an introduction to the relativistic quantum theory of Dirac particles and the methods of Feynman that are employed in his formulation of positron theory. Applications are made to scattering problems and to general problems of atomic and molecular structure. Mr. Park

PY 612 ADVANCED QUANTUM MECHANICS 3(3-0) S
Prerequisites: PY 601, PY 611

A general propagator treatment of Dirac particles, photons, and scalar and vector mesons, with an introduction to quantum electrodynamics and S-matrix theory. Applications of Feynman graphs and rules will be given illustrating basic techniques employed in the treatment of electromagnetic, weak and strong interactions. Renormalization theory, the effects of radiative corrections and aspects of the general Lorentz covariant theory of quantized fields will also be considered.
Mr. Park

PY 622 STATISTICAL MECHANICS 3(3-0) S
Prerequisites: PY 413, PY 501, PY 503

A study of classical and quantum statistical mechanics, including the time evolution of systems near equilibrium. The wide range of applications presented is selected both to display elements of formal structure or analytical techniques in the theory and to illustrate stochastic treatment of the bulk properties of commonly studied physical systems. Mr. Ridgeway

PY 630, 631 NUCLEAR STRUCTURE PHYSICS I, II 3(3-0) FS
Prerequisites: PY 502, PY 510

Advanced description of nuclear models and nuclear reactions. Topics include: internucleon forces, compound nucleus processes, shell model, optical model, R-matrix theory, direct reactions, collective model, electromagnetic transitions, isobaric analog states. Mr. Mitchell

PY 641 NON-INERTIAL SPACE MECHANICS 3(3-0) S
Prerequisites: MA 661, PY 601
Corequisite: PY 602

This course treats the theoretical description of the phenomena of mechanics relating to noninertial frames of reference, with applications to space travel and the instrumentation problems of rocketry. Applications to inertial guidance and electromagnetic-inertial coupling effects are also considered. Mr. Davis

PY 651 MATHEMATICS OF SOLID-STATE AND MANY BODY THEORY 3(3-0) F
Prerequisites: MA 513, PY 502, PY 552

Topics treated include multidimensional Fourier techniques, Schwartz distributions, Green's functions, Brillouin zones, Fermi surfaces, correlation coefficients, Patterson functions and dispersion relations. Study is made of the physical meaning of mathematics as used in current research in physics. Mr. Hall

PY 652 COOPERATIVE PHENOMENA IN SOLIDS 3(3-0) S
Prerequisite: PY 651

Classical and quantum theories of equilibrium and transport properties of ferromagnetism, antiferromagnetism, and order-disorder in alloys. Statistical mechanics of, and phase transitions in, these and other systems are treated.
Mr. Hall

PY 655 (MA 655) QUALITATIVE METHODS IN CELESTIAL MECHANICS 3(3-0) F

(See mathematics, page 217.)

PY 656 (MA 656) PERTURBATION THEORY IN CELESTIAL MECHANICS 3(3-0) S

(See mathematics, page 217.)

The following five courses offer opportunities for advanced study in special areas of physics under staff members working in these areas.

PY 690 SPECIAL TOPICS IN MOLECULAR PHYSICS 1-6 FS
Prerequisite: Consent of instructor

PY 691 SPECIAL TOPICS IN NUCLEAR PHYSICS 1-6 FS
Prerequisite: Consent of instructor

PY 692 SPECIAL TOPICS IN PLASMA PHYSICS 1-6 FS
Prerequisite: Consent of instructor

PY 693 SPECIAL TOPICS IN SOLID STATE PHYSICS 1 6 FS
Prerequisite: Consent of instructor

PY 694 SPECIAL TOPICS IN THEORETICAL PHYSICS 1-6 FS
Prerequisite: Consent of instructor

PY 695 SEMINAR 1(1 0) FS

Reports on topics of current interest in physics. Several sections are offered so that students with common research interests may be grouped together.
Graduate Staff

PY 699 RESEARCH Credits Arranged

Graduate students sufficiently prepared may undertake research in some selected field of physics. Graduate Staff

Physiology

GRADUATE FACULTY

Professors: LEMUEL GOODE, CHARLES H. HILL, ERNEST HODGSON, IAN S. LONGMUIR, HENRY L. LUCAS, JR., LESTER C. ULBERG; *Adjunct Professor:* DOUGLAS H. K. LEE; *Associate Professors:* EDWARD V. CARUOLO, JOHN F. ROBERTS, DONALD E. SMITH, ROBERT T. YAMAMOTO; *Assistant Professors:* BRYAN H. JOHNSON, THOMAS E. LEVERE, WILLIAM P. MARLEY, JAMES P. THAXTON

Graduate study under the direction of the physiology faculty may lead to the Master of Science and the Doctor of Philosophy degrees. The physiology faculty is an interdepartmental group drawn from the departments participating in the program. They are: animal science, biochemistry, entomology, physical education, poultry science, psychology, statistics and zoology. The program emphasizes the comparative approach implicit in this type of organization.

Experimental facilities of the above departments are available for physiological research, as well as such special facilities as the Reproductive Physiology Laboratory and the Wrightsville Marine Biomedical Laboratory. Experimental animals available cover a wide range, from insects and other invertebrates to large mammals.

In addition to courses in physiology, majors in the program are expected to take selected courses in biochemistry and cell biology. Minors are usually chosen from such fields as biochemistry, cell biology, entomology, statistics, genetics and zoology. A strong basic knowledge in one of these areas is essential.

Financial assistance for qualified students in the form of research assistantships, fellowships and traineeships is available through participating departments. Prospective students may obtain further information by writing to any one of the graduate faculty listed above or to the Chairman, Physiology Program, P. O. Box 5306, N. C. State University, Raleigh, North Carolina 27607.

Graduate students enrolled as physiology majors are located in the department of their major professor and may participate in the activities of that department.

PHY 502 (ANS 502) REPRODUCTIVE PHYSIOLOGY OF VERTEBRATES 3(3-0) S
(See animal science, page 67.) Mr. Ulberg

PHY 513 (ZO 513) COMPARATIVE PHYSIOLOGY 4(3-3) S
(See zoology, page 333.) Graduate Staff

PHY 553 (BCH 553) PHYSIOLOGICAL BIOCHEMISTRY 3(3-0) S
(See biochemistry, page 73.)

PHY 575 (ZO 575, ENT 575) PHYSIOLOGY OF INVERTEBRATES 3(3-0) F
Prerequisite: Consent of instructor

The course deals with the physiology of the invertebrates, including the Insecta but excluding the Protozoa. The unity of the physiology of the various groups is stressed, and the relationship of physiology to contemporary biology and to other related biological fields will be illustrated. Graduate Staff

PHY 590 SPECIAL PROBLEMS IN PHYSIOLOGY Credits Arranged F
Prerequisites: Graduate standing, consent of instructor

Beginning course for physiology graduate students. Graduate Staff

PHY 604 (ANS 604) EXPERIMENTAL ANIMAL PHYSIOLOGY 4(2-4) F
(See animal science, page 68.) Mr. Caruolo

PHY 690 PHYSIOLOGY SEMINAR 1(1-0) S
Prerequisite: Graduate standing

Graduate Staff

PHY 695 SELECTED TOPICS IN PHYSIOLOGY 1-4
Prerequisite: Graduate standing

Graduate Staff

PHY 699 PHYSIOLOGICAL RESEARCH Credits Arranged FS
Prerequisites: Graduate standing, consent of instructor

Graduate Staff

COURSES FROM ASSOCIATED DEPARTMENTS

PO 524 (ZO 524) COMPARATIVE ENDOCRINOLOGY

BCH 551 GENERAL BIOCHEMISTRY

ZO 614 ADVANCED CELL BIOLOGY

OTHER SUPPORTING COURSES AVAILABLE

ENT 611 BIOCHEMISTRY OF INSECTS

GN 532 (ZO 532) BIOLOGICAL EFFECTS OF RADIATIONS

PSY 502 PHYSIOLOGICAL PSYCHOLOGY

ZO 510 ADAPTIVE BEHAVIOR OF ANIMALS

Plant Pathology

GRADUATE FACULTY

Professor Don E. Ellis, *Head*

Professors: Jay L. Apple, Robert Aycock, Kenneth R. Barker, Carlyle N. Clayton, Ellis B. Cowling, Charles B. Davey, Eddie Echandi, Teddy T. Hebert, George B. Lucas, Lowell W. Nielsen, Charles J. Nusbaum, Nathaniel T. Powell, Joseph N. Sasser, David L. Strider, Hedwig H. Triantaphyllou, Nash N. Winstead; *Professors USDA:* Charles S. Hodges, Jr., David M. Kline, John P. Ross; *Adjunct Professors:* George H. Hepting, Robert G. Owens; *Extension Professor:* J. C. Wells; *Professors Emeritus:* Samuel G. Lehman, Frederick L. Wellman; *Associate Professors:* Guy V. Gooding, Jr., Larry F. Grand, Donald Huisingh, Samuel F. Jenkins, Jr., Michael P. Levi, Robert D. Milholland, Royall T. Moore; *Associate Professors USDA:* Harvey W. Spurr, Jr., Ronald E. Welty; *Extension Associate Professor:* Harry E. Duncan, *In Charge; Adjunct Associate Professors:* Jerome W. Koenigs, E. George Kuhlman, Richard A. Reinert; *Assistant Professors:* Marvin K. Beute, Leon T. Lucas, Charles E. Main, C. Gerald Van Dyke; *Assistant Professor USDA:* Kurt J. Leonard; *Adjunct Assistant Professors:* Allen S. Heagle, Ronald W. Pero; *Extension Assistant Professor:* Charles W. Averre, III

The Department of Plant Pathology offers programs leading to both the Master of Science and Doctor of Philosophy degrees. Strong foundation courses in mathematics, biology, chemistry, physics and soil science are usually prerequisite for admission to candidacy for the Ph.D. degree. For students who wish more general training without the thesis requirement, the Master of Life Sciences degree is offered, with major emphasis in plant pathology.

One of the principal objectives of graduate education in plant pathology is to develop the student's ability to conduct independent research which leads to the development of new knowledge. There are many opportunities for employment, especially in research, extension and teaching at land-grant colleges and experiment stations. The United States Department of Agriculture and industry also conduct programs which utilize plant pathologists. The rapid development of agricultural chemicals for disease control offers numerous opportunities in research, promotion and service. Plant pathologists also may participate in foreign service through international and federal organizations, as well as in commercial enterprises.

In addition to excellent facilities for training in general phytopathology, separate, fully-equipped laboratories for research in nematology, virology, physiology of pathogenesis and special biochemical problems are available to the student. In-depth training in all of these particular areas is available.

The department has excellent greenhouse facilities and controlled environmental studies in a new Phytotron recently completed. Student participation in the Plant Disease Clinic provides excellent training and experience in the diagnosis of all types of plant diseases and disorders.

The wide range of soil types and climatic areas in North Carolina makes possible the commercial production of a variety of field, vegetable and ornamental crops, as well as forest trees. Special facilities for experimental work on diseases of these crops are available at some sixteen permanent research stations located throughout the state.

The department has a number of graduate fellowships and assistantships at stipends adjusted to the previous training and experience of the recipients. These have included commercial assistantships and fellowships, National Science Foundation Traineeships, National Defense Education Act fellowships, National Aeronautics and Space Agency fellowships, E. G. Moss and W. E. Cooper Memorial fellowships, and Agricultural Foundation and departmental assistantships. Students applying directly for fellowships from the National Science Foundation, the National Institutes of Health and other granting agencies are invited to specify the department as host institution.

FOR GRADUATES AND ADVANCED UNDERGRADUATES

PP 500 PLANT DISEASE CONTROL 3(2-3) S
Prerequisite: PP 315

Disease control strategies and tactics are developed in a practical manner. Control economics and practices are considered in relation to principles and current research on biological, cultural, physical and chemical methods. Disease resistance and regulatory methods are also discussed. Messrs. Jenkins, Spurr

PP 501 PHYTOPATHOLOGICAL METHODS 4(2-6) F
Prerequisites: PP 315, consent of instructor

A study of the principles of phytopathological research. The course is designed to apply the classical scientific method to the investigation of plant disease. Consideration will be given to appraising disease problems, reviewing the literature, isolating pathogens, inoculating with pathogens, measuring and controlling environment, histopathological studies, collecting and evaluating data, and manuscript preparation. Staff

PP 502 PHYTOPATHOLOGICAL PRINCIPLES 4(3-3) S
Prerequisites: PP 315, consent of instructor

A study of general principles of plant pathology including in-depth study of selected diseases. The basic concepts of etiology, pathology, epidemiology, and control will be considered. Mr. Powell

PP 503 IDENTIFICATION OF PLANT PATHOGENIC FUNGI 3(4-12) Sum.
Prerequisite: Mycology or one advanced course in plant pathology

A study of the recognition and identification of fungi which cause plant diseases and the differentiation of fungal diseases from those caused by other agents. Special consideration will be given to use of keys in the identification of fungi and the major sources of descriptive information on plant pathogens. (Offered first summer session 1972 and alternate years.) Mr. Hodges

PP 545 PLANT VIRUSES 2(1-3) S
Prerequisite: PP 501 or equivalent

Development of the concept of viruses as plant pathogens, nature and properties of viruses, symptomatology, methods of transmission, identification, introduction to purification procedures, antiserum production, serological tests, epidemiology and control. Mr. Gooding

PP 550 NEMATODE DISEASES OF PLANTS AND THEIR CONTROL 2(1-3) F
Prerequisite: PP 315 or equivalent

A study of plant diseases caused by nematodes. Special consideration will be given to host-parasite relationships, host ranges and life cycles of the more important economic species. Principles and methods of control will be emphasized.
Mr. Sasser

PP 575 (MB 575, BO 575) THE FUNGI 3(3-0) S

(See botany, page 84.)

PP 576 (MB 576, BO 576) THE FUNGI LAB 1(0-3) S

(See botany, page 84.)

PP 595 SPECIAL PROBLEMS IN PLANT PATHOLOGY Credits Arranged
Prerequisite: Consent of instructor Maximum 6

Investigation of special problems in plant pathology not related to a thesis problem. The investigations may consist of original research and/or literature survey. Staff

FOR GRADUATES ONLY

PP 604 MORPHOLOGY AND TAXONOMY OF NEMATODES 3(1-6) S
Prerequisites: PP 550, consent of instructor

A study of the morphology, anatomy and taxonomy of nematodes with emphasis on the identification of important plant-parasitic genera. Exercises include preparation of semipermanent and permanent nematode mounts.
Mrs. Triantaphyllou

PP 605 PLANT VIROLOGY 3(1-6) F
Prerequisites: PP 315, GN 411, and a course in organic chemistry

A study of plant viruses including effects on host plants, transmission, classification, methods of purification, determination of properties, chemical nature, structure and multiplication. (Offered 1973 and alternate years.) Mr. Hebert

PP 608 HISTORY OF PHYTOPATHOLOGY 1(1-0) F
Prerequisites: PP 315, consent of instructor

Development of the science of phytopathology from its early beginnings to the early part of the 20th century. (Offered 1973 and alternate years.) Mr. Ellis

PP 609 CURRENT PHYTOPATHOLOGICAL RESEARCH UNDER FIELD CONDITIONS 2(1-3) S
Prerequisite: Graduate standing

Study of concepts involved, procedures used and evaluation made in current phytopathological research by plant pathology staff. Visits to various research stations will be made by the class. Mr. Clayton

PP 611 ADVANCED PLANT NEMATOLOGY 3(2 3) S
Prerequisite: PP 604

A study of the biology, physiology and ecology of plant parasitic nematodes with emphasis on mechanisms of pathogenesis, host responses to infection and population dynamics. Laboratory exercises will include methods of cultivating nematodes and means of determining nutritional requirements, special physiological techniques and approaches used in ecological investigations. (Offered 1972 and alternate years.) Mr. Barker

PP 612 PLANT PATHOGENESIS 3(2-3) F
Prerequisites: PP 500 and consent of instructor

The following major topics will be considered: Infection processes, alterations in photosynthesis, respiration, nitrogen metabolism, vascular function and growth regulator function. The biochemical nature of the weapons utilized by pathogens in pathogenic attack and the defensive mechanisms employed by the hosts in

resisting attack and the resultant dynamic interactions will be the central theme of the course. (Offered 1972 and alternate years.) Mr. Huisingh

PP 614 NEMATODE DEVELOPMENT, CYTOLOGY AND GENETICS 2(1-3) F
Prerequisite: PP 604 or consent of instructor

A study of embryogenesis, post-embryonic development, gametogenesis, cytology, reproduction, sexuality, genetics and evolution of nematodes with emphasis on plant-parasitic forms. Laboratory exercises include small research projects in each area of study and demonstrations of techniques and materials. (Offered 1972 and alternate years.) Mr. Triantaphyllou

PP 625 (BO 625) ADVANCED MYCOLOGY 4(2-6) F
Prerequisite: PP 575 or consent of instructor

An in depth treatment of major groups of fungi. Aspects of taxonomy, nomenclature, developmental morphology, genetics, host-parasite relations, physiology and ecology will be presented. Laboratories will provide opportunities to study cardinal characteristics of selected fungi representing the major groups; field observations and collecting will also be included. (Offered 1972 and alternate years.) Mr. Grand

PP 650 COLLOQUIUM IN PLANT PATHOLOGY 3(3-0) F
Prerequisite: PP 502 or consent of instructor

Group discussion of prepared topics assigned by the instructor with the view of developing a thorough understanding of basic concepts and their significance in the etiology, pathogenesis, epidemiology and control of plant diseases. Attention will be given to the genesis and evolution of fundamental ideas and values and how the development of new techniques and the acquisition of new knowledge influences the advancement of plant pathology and its various specialized fields. (Offered 1973 and alternate years.) Mr. Nusbaum, Graduate Staff

PP 690 SEMINAR IN PLANT PATHOLOGY 1(1-0) FS
Prerequisite: Consent of seminar chairman

Discussion of phytopathological topics selected and assigned by seminar chairman. Graduate Staff

PP 699 RESEARCH IN PLANT PATHOLOGY Credits Arranged
Prerequisites: Graduate standing, consent of instructor

Original research in plant pathology. Graduate Staff

Politics

GRADUATE FACULTY

Professor WILLIAM J. BLOCK, *Head*
Professors: FRED V. CAHILL, JR., JOHN T. CALDWELL, ABRAHAM HOLTZMAN, ROBERT O. TILMAN, *Dean, School of Liberal Arts; Professor Emeritus:* PRESTON W. EDSALL; *Associate Professors:* HARVEY G. KEBSCHULL, JACKSON M. MCCLAIN, KEITH S. PETERSEN; *Assistant Professor:* J. OLIVER WILLIAMS

The Department of Politics offers a program of graduate studies leading to a Master of Arts degree and a Master of Public Affairs degree.

A candidate for admission to either program must have demonstrated an aptitude for graduate study in politics; he may also be required to take certain fur-

ther undergraduate courses to make up any deficiencies that may exist in his record.

The Master of Public Affairs degree requires completion of a 36 semester hour professional program for persons who are now or hope to be employed by government or by a government related private enterprise or association. It does not require competence in a foreign language or a thesis.

Approximately half of the program (18-27 hours) is to be selected from courses offered by the Department of Politics. Here students may concentrate either in administration or in the wider field of political institutions and processes. The remaining hours (9-18) may be taken in one or more disciplines, such as psychology, sociology, economics, statistics, operations research, history or English. Or if the participant prefers, he may take the optional courses in some area of technology, such as forestry, civil engineering, adult education and industrial engineering.

Students who enroll in the program should have completed nine hours in the social sciences (including three in government) as undergraduates and have achieved a B average in the undergraduate major.

The Master of Arts degree requires each candidate to complete 30 hours of graduate work. Eighteen to 21 of these, including three hours of thesis, will be in two major fields in the Department of Politics. Major fields are to be selected from the following: political theory, American politics, comparative politics, international relations and public administration. Nine to 12 hours will be in a minor field outside the Department of Politics. In either case a student's work in his minor field must constitute a unified pattern and must contribute to one or both of his major fields. Each student will be assigned to a graduate committee chairman for the preparation of his program of study which shall be subject to the approval of two other committee members, including one from outside the Department of Politics.

Scope and Method of Politics (PS 509) is required of every candidate for both degrees. In addition to this particular course, a candidate for the Master of Arts degree must: demonstrate reading proficiency in one modern language (normally German, French, Spanish or Russian); write a thesis in one of his major areas; and take a comprehensive written examination in his major fields and an oral examination on his thesis and the major field in which it is written and on his minor.

FOR ADVANCED UNDERGRADUATES

PS 401 AMERICAN PARTIES AND PRESSURE GROUPS 3(3-0) F

After a brief survey of those features of American government essential to an understanding of the political process, the course proceeds to examine the American electorate and public opinion and devotes its major attention to the nature, organization and programs of pressure groups and political parties and to their efforts to direct opinion, gain control of government and shape public policy. Special attention is given to party organization and pressure group activity at the governmental level and to recent proposals to improve the political party as an instrument of responsible government. Mr. Holtzman

PS 403 BLACK AMERICANS IN AMERICAN POLITICS 3(3-0) F Sum.
Prerequisite: Six hours of social science

The study of the political activity of the Afro-American. The sources of and the kinds of attitudes he brings into the American political system; the contrast in political activity engaged in by different black groups and reasons for the differences; the impact of the Black's efforts on policy-making institutions such as city

councils, legislatures and executive branches of government at the state and national level.

PS 404 BLACK POLITICAL IDEOLOGY 3(3 0) S Sum.
Prerequisite: Six hours of social science

The study of the political thought of Black and non-Black political thinkers on the problems, struggle and movement of the Afro Americans. Black political ideology will be related to the Afro American movement for social change and it will be placed into the mainstream of traditional and modern political philosophy.

PS 405 NATIONAL SECURITY POLICY 3(3-0) S Sum.
Prerequisite: PS 321

An investigation into 1) the making of security policy, including the roles of the Executive, Congress and non governmental actors; 2) the evolution of changing assumptions, strategies, and goals; and 3) the nature of the U.S. security requirements, U.S. military commitments abroad, and the "costs" of strategies based on arms superiority, arms control and disarmament.

PS 406 POLITICS AND POLICIES OF AMERICAN STATE GOVERNMENTS 3(3-0) FS Sum.
Prerequisite: PS 201 or consent of instructor

Selected problems arising from the operation of legislative, administrative and judicial machinery. In addition to acquiring a comprehensive view of these problems each student will make an intensive study of a special phase of one of them. Special attention will be given to North Carolina. Mr. Williams

PS 421 SOVIET AND SOVIET BLOC FOREIGN POLICY 3(3-0) FS
Prerequisite: Junior standing

This course examines the elements of continuity and change in Soviet foreign policy from 1917 to the present and the post World War II policies of the Eastern European states. Foreign policy decisions are examined in light of the national interests of the Soviet Union and the Eastern European states. Special attention is given to the emergence of polycentrism, the Sino-Soviet split and Soviet bloc relations with the West.

PS 431 INTERNATIONAL ORGANIZATION 3(3-0) S

A study of the evolving machinery and techniques of international organization in the present century with particular emphasis on recent developments. The actual operation of international organization will be illustrated by the study of selected current international problems. Mr. Petersen

PS 461 PUBLIC OPINION IN DEMOCRACIES 3(3-0) FS
Prerequisite: Three hours of politics

The course is designed to develop a knowledge of the nature of public opinion and its functions in a democratic system of government. It focuses primarily on public opinion in the United States but also makes comparisons with other nations. The areas of emphasis are: theories concerning opinion formation and functions, research methodology, public opinion and policy development, and empirical studies on public opinion.

PS 471 LATIN AMERICA IN WORLD AFFAIRS 3(3-0) S
Prerequisite: PS 376 or consent of instructor

This course examines the role of the Latin American states in world affairs, as individual states and as a region acting through international organizations. Attention is given to the historical, political, economic, social and geographic forces conditioning the foreign policies of these countries. Emphasis is placed on the relations of the Latin American countries with the United States.

PS 472 SOVIET POLITICS 3(3-0) FS

This course focuses on the contemporary Soviet political system, its structure, functions and processes, with brief consideration of the historical and ideological base of Soviet politics. As a course in comparative politics, the analysis will proceed within a framework designed to elucidate the similarities and differences of the Soviet system with other political systems. In addition, the Soviet system will be tested against a theoretical model of totalitarian dictatorships.

PS 473 POLITICAL SYSTEMS OF NEW STATES 3(3-0) F

This course explores the general characteristics of the political systems of the new states in Asia and Africa. Following a brief survey of the pattern and nature of colonialism, the independence movements, and the contemporary social and economic conditions of the new states, the course focuses on political ideologies, elites, and organizations and processes. Particular attention is given to the role of intellectuals and the military. The course concludes with an examination of major political, social and economic problems. Mr. Kebschull

PS 493 SEMINAR ON THEORIES OF POLITICAL VIOLENCE AND NONVIOLENCE 3(3 0) S Sum.

Prerequisite: Junior standing

This course will focus upon the use of violence and nonviolence as methods for resolving conflict in a variety of national and international political arenas. The principal questions that will be considered include: What types of individuals, groups, or governments are likely to employ violent or nonviolent political behaviors? What motivations do political actors have for using these strategies? In what types of political, economic, and social situations is violence likely to occur? What are the outcomes of violent and nonviolent strategies of political conflict resolution?

PS 494, 495 (EC 494, 495; SOC 494, 495) URBAN SEMINAR 3(3-0) FS
Prerequisite: Junior standing

A study of urban and urban-related problems through theories from the disciplines of politics, sociology and economics, and their application to an existing environment. Intermixed with formal study will be field research in various local communities. In addition, students will be involved with both public and private agencies and with local leaders in ongoing programs in Raleigh and adjacent communities.

PS 496 GOVERNMENTAL INTERNSHIP AND SEMINAR 3-6 S Sum.
Prerequisites: Junior standing, consent of the committee of selection

Governmental internship involving formal seminars; lecture-discussions by political scientists, legislators, executives, judges, representatives of special interests and news media; four to six hours a day working on assignment to and under supervision of legislators or executives; formal report at completion of an internship covering the various aspects of the program.

PS 498 SPECIAL TOPICS 3(3-6) FS
Prerequisite: Six hours of politics

The student will make a detailed investigation of a special topic in politics. The topic and mode of study will be determined by the student and a member of the department's faculty.

FOR GRADUATES AND ADVANCED UNDERGRADUATES

PS 500 POLITICAL THOUGHT: PLATO TO THE REFORMATION 3(3-0) F
Prerequisite: Consent of instructor

The emergence and development of the theories underlying or explaining the

political aspects of behavior, approached through the study of the writings of the principal political philosophers from the days of the Greek city-state to the Reformation. Graduate Staff

PS 501 MODERN POLITICAL THEORY 3(3 0) S
Prerequisite: Consent of instructor

A study of the state and its relationship to individuals and groups, approached through reading of selected passages from the works of outstanding philosophers from the 16th century to the present. Graduate Staff

PS 502 (ED 502) PUBLIC ADMINISTRATION 3(3-0) FS Sum.
Prerequisite: PS 200 or consent of instructor

A study of the factors which contribute to goal displacement in public agencies and the institutions, concepts and techniques which may be used in such agencies to reduce the effects of these factors. Messrs. Block, McClain

PS 503 COMPARATIVE ADMINISTRATION 3(3-0) FS
Prerequisite: PS 502 or PS 473 or consent of instructor

Concentration will be on administrative systems of developing nations with limited attention to developed systems. The major emphasis will be on administrative aspects of governmental change and modernization of developing nations; colonial influence on administration; problems of establishing new nations and adapting to change in established states; bureaucratic development and behavior; theories of development administration. Graduate Staff

PS 505 CONTEMPORARY POLITICAL THEORY 3(3-0) S
Prerequisite: Consent of instructor

The course will focus upon major topics in contemporary political theory, including the relationship between political science theory and political philosophy; the foundations, conditions and prospects of democratic forms of government; bureaucratization and democratic values; theories of mass society; violence and revolution as possible instruments of democratic change; human nature and politics; and dilemmas of modern citizenship. Attention will be given to the actual and potential contributions of empirical studies to the analysis of the various topics. The range of writers studied will extend from social scientists, such as Robert Dahl and Seymour Lipset, to political philosophers, such as Leo Strauss, Herbert Marcuse, and Albert Camus. Graduate Staff

PS 506 PUBLIC PERSONNEL ADMINISTRATION 3(3-0) Sum.
Prerequisite: PS 502 or consent of instructor

A study in depth of the institutions and the sequence of processes in public personnel administration. It examines existing practices but is primarily concerned with emerging theories and trends. Graduate Staff

PS 507 COLLECTIVE NEGOTIATIONS IN THE PUBLIC SERVICE 3(3-0) Sum.
Prerequisite: PS 201 or consent of instructor

This course includes intensive consideration of the background of collective negotiations movement; analysis of key policy issues, such as bargaining rights and use of strike weapons; framework for collective negotiations; scope and conduct of negotiations; impasse resolution; grievance procedure. Graduate Staff

PS 509 SCOPE AND METHODS OF POLITICS 3(3-0) FS Sum.
Prerequisite: PS 200 or consent of instructor

This course reviews contemporary theories, concepts and methods fundamental to the study of politics. It emphasizes current empirical research and the collateral

involvement in research activities aimed at the development of basic skills in this area. Mr. Williams

PS 510 (EC 510) PUBLIC FINANCE 3(3-0) F
(See economics, page 121.)

PS 511 THE BUDGETARY PROCESS 3(3-0) S Sum.
Prerequisites: Consent of instructor, at least nine hours in the social sciences including a course in American Government

A study of the generalized budgetary process used at all levels of government in the United States. Understanding of the process is based upon comprehension of the institutions involved, the roles of politicians and professionals, and the objectives of budgetary systems. The course will also focus upon budgetary reforms and the expanding Planning-Programming-Budgeting System as a management tool. Mr. McClain

PS 512 AMERICAN CONSTITUTIONAL THEORY 3(3-0) F
Prerequisite: PS 200 or equivalent

Basic constitutional doctrines, including fundamental law, judicial review, individual rights and political privileges, and national and state power. Special attention is given to the application of these doctrines to the regulation of business, agriculture and labor and to the rights safeguarded by the First, Fifth and 14th Amendments to the Constitution. Mr. Cahill

PS 515 AMERICAN POLITICAL THOUGHT 3(3-0) FS Sum.
Prerequisite: Senior or graduate standing

The course will examine and evaluate major American writings on the nature and purpose of politics. Readings will be grouped under the following topics: (1) Various interpretations of the American Constitution and the principles embodied therein; (2) Writings on civil and natural rights; (3) The character of American Liberalism; (4) Black American political thought and (5) The contemporary crisis in Liberal thought. The purpose is to develop the independent capacity to read and reflect with care on the grounds of different views about American politics. Graduate Staff

PS 516 PUBLIC POLICY ANALYSIS 3(3-0) FS
Prerequisites: Graduate standing; advanced undergraduate standing and consent of instructor

This course will focus on the theories and methodology of analyzing and explaining public policy and the substance of recent domestic policies in the human and physical resources area, including welfare, poverty, education, housing, urban renewal, transportation, recreation-conservation and agriculture. Mr. Williams

PS 520 URBAN POLITICS 3(3-0) F
Prerequisite: PS 206

A comparative study of political conditions in cities and localities. Topics will include the formal structures and rules of city and metropolitan governments, and the relationships to the informal norms and distribution of power; patterns of local decision-making: elite recruitment and citizen participation; variations of local autonomy and the scope of local politics; and approaches to urban policy issues. Graduate Staff

PS 521 PROBLEMS IN URBAN AND METROPOLITAN AREA GOVERNMENT 3(3-0) S
Prerequisite: PS 206 or consent of instructor

This course examines theory and research on problems affecting governments

in metropolitan areas. Principal attention is given to those problems which affect (or result from) governmental structure, institutions and politics and to the alternative approaches to their solution. Graduate Staff

PS 522 SEMINAR ON WAR AND PEACE IN THE INTERNATIONAL SYSTEM 3(3-0) F Sum.
Prerequisite: Senior standing

This seminar will focus upon war and peace in the international system; in particular, the circumstances under which violent international conflict is likely and the factors that enhance the probability that the conflicts will be resolved by peaceful means. Consideration will not only be given to the wars and problems of the past but also to alternative future worlds in which war or peace might be prevalent. The course will focus on empirical theory and research including the work of peace theorists and future researchers. Graduate Staff

PS 531 THE LEGISLATIVE PROCESS 3(3-0) S
Prerequisite: PS 206 or consent of instructor

A study of the formulation of public policy from the institutional and behavioral viewpoints. Important current legislative problems at the congressional and state legislative levels will be selected and will serve as a basis for analyzing the legislative process. Mr. Holtzman

PS 532 THE CHIEF EXECUTIVE 3(3-0) F Sum.
Prerequisite: PS 200 or PS 201

This course will focus upon three major concepts of the office of the chief executive, as developed under several incumbents. First are the institutions which surround that office and which facilitate the expansion of its power and operations. Next are the various roles, which are played with more or less success by different chief executives. Last are the processes of leadership by which the chief executive can attempt to direct the machinery of government to achieve predetermined objectives. Messrs. Block, Holtzman

PS 533 THE JUDICIAL PROCESS 3(3-0) S
Prerequisite PS 200 or PS 201

A comparative examination of the judicial process in the United States, England and France. After a brief examination of the nature and main categories of law, the course will cover such matters as staffing of courts, the participants in litigation, the American judicial system, special consideration of the role of the U.S. Supreme Court, court systems in the countries listed above and finally a thorough examination of judicial review in action. Administrative tribunals will receive some attention. Mr. Cahill

PS 542 GOVERNMENTAL PLANNING 3(3-0) F Sum.
Prerequisite: PS 502 (ED 502)

A study of the planning function at all levels of government in the United States, with particular attention to the problems posed for planning by the rapid growth of metropolitan areas. Mr. McClain

PS 572 SEMINAR IN COMPARATIVE POLITICS 3(3-0) FS
Prerequisite: One course in comparative politics

This seminar will open with a survey of the problems and methods of comparative political analysis, after which students will be assigned a specific, limited subject to be examined within the framework of a systematic, analytical scheme appropriate to the topics. Specific topics will be drawn from the subjects of political ideologies, political groups, political elites, and decision-making institutions and processes. Mr. Kebschull

PS 575 POLITICAL DEVELOPMENT 3(3-0) FS
Prerequisite: Nine hours of political science

This course examines the concept, theories, characteristics and problems of political development. Within a broad historical framework, particular subjects are analyzed in relationship to political development. These subjects include, among others, political culture, political integration, political institutions, military forces and economic development. Data derived from comparative cultural and political studies are employed in an attempt to discover patterns of change related to political development. Mr. Kebschull

PS 578 COMPARATIVE COMMUNIST SYSTEMS 3(3-0) FS
Prerequisite: A comparative government course or consent of instructor

A study of the international Communist movement and the evolution of the international sub-system of Communist states. Focuses on the Soviet and Chinese systems as alternative models for development in Communist and non-Communist states. Additional emphasis is placed on the institutional, political and ideological similarities and differences within the Communist world and major Communist parties outside the Communist state system. Graduate Staff

FOR GRADUATES ONLY

PS 601 SEMINAR IN PARTY AND GROUP POLITICS 3(3 0) S
Prerequisites: PS 401, consent of instructor

This course examines in depth such problems as mobilization of consent, recruitment of leaders, financing and conduct of campaigns, nomination processes, interparty and intraparty politics, party-interest group relations and ideology, and party-interest group relations with government and public policy. Short research papers will be required, some of which will be presented and evaluated in class. Mr. Holtzman

PS 602 SEMINAR IN LEGISLATIVE PROBLEMS 3(3-0) F
Prerequisites: Graduate standing, consent of instructor

This seminar considers basic problems characteristic of American legislative systems: development and maintenance of formal and informal rules of the game; relationships between outside inputs (by parties, interest groups, constituents, executives, courts) and legislators; strategies and tactics of leadership; committee decision-making, roles and role behavior of legislators; bicameral and apportion ment problems. Each student is required to do extensive reading, to interview legislators and those who seek to influence them, and to prepare reports.
Mr. Holtzman

PS 603 SEMINAR IN ADMINISTRATIVE PROBLEMS 2-4 S Sum.
Prerequisite: PS 502 or equivalent

An advanced course in administrative principles and methods. Students will perform individual or group research, under supervision, in specific administrative topics within the context of those public agencies which function in their respective fields of technology. Mr. Block

PS 604 SEMINAR IN JUDICIAL PROBLEMS 3(3-0) F
Prerequisites: Graduate standing; PS 533 or equivalent

Building on previously acquired familiarity with the judicial process, this course requires the student to work in depth on one or more contemporary judicial problems and to use various research techniques in his study. Mr. Cahill

PS 605 SEMINAR IN ORGANIZATIONAL THEORY 3(3-0) FS
Prerequisite: PS 502 (ED 502)

A seminar in which the students read, analyze and discuss the original writings of some of the major theories of organizational structures and behavior. It will focus upon classical management theory, the human relations theories, and recent empirical and integrative organizational theories. Among the writers upon whose works the seminar will focus are Max Weber, Mary Parker Follett, Luther Gulick, Frederick Taylor, Elton Mayo, F. J. Roethlisberger, Chester Barnard, Herbert Simon, Amiti Etzioni, Robert Presthus, Victor Thompson, and Robert Golembiewski. Organization theories are based upon studies of both private and public organizations, so the literature of both areas is relevant. However, most of the emphasis upon current theories will focus on the public or governmental sector. Mr. Block

PS 606 SEMINAR IN POLICY AND ADMINISTRATION 3(3-0) F
Prerequisites: PS 502 (ED 502) and three additional hours in administration

A seminar in theories and techniques of administration in applied situations, using case study techniques. Mr. McClain

PS 621 SEMINAR IN INTERNATIONAL POLITICS 3(3-0) F
Prerequisites: Graduate standing, consent of instructor

Examination in depth of selected theories, practices and problems of international politics. Mr. Petersen

PS 696 SEMINAR IN POLITICS 2-4 F
Prerequisite: Advanced graduate standing

An independent advanced research course in selected problems of government and politics. The problems will be chosen in accordance with the needs and desires of the students registered for the course. Graduate Staff

PS 699 RESEARCH IN POLITICS Credits Arranged FS
Prerequisites: Graduate standing, consent of adviser

Research for and writing of master's thesis. Graduate Staff

Poultry Science

GRADUATE FACULTY

Professor ROBERT E. COOK, *Head*
Professors: HARVEY L. BUMGARDNER, WILLIAM E. DONALDSON, EDWARD W. GLAZENER, PAT B. HAMILTON, CHARLES H. HILL, JR.; *Extension Professor:* JAMES R. HARRIS; *Associate Professor:* WILLIAM L. BLOW; *Assistant Professor:* JIMMY D. GARLICH

The Department of Poultry Science offers the Master of Science degree in poultry science. Doctoral programs are offered in the disciplines of microbiology, physiology, genetics and nutrition.

The Department of Poultry Science occupies Scott Hall, a building containing well-equipped laboratories, animal rooms and offices. Additional research facilities are located on the University farm as well as on outlying farms in the Piedmont and eastern sections of North Carolina. New animal facilities were recently completed at Scott Hall which greatly increase the research capacity of the department.

The Dearstyne Avian Health Center, a three building complex, has recently been completed and is being used in connection with special research projects related to disease resistance and the treatment of various pathological conditions. The complex is made up of animal isolation rooms, biochemical laboratories and related facilities.

The research program is comprehensive and includes fundamental studies in nutrition, physiology, genetics, pathology and microbiology. In addition, investiga tion of problems of more practical urgency is undertaken when appropriate.

The demand for men and women with advanced training in poultry science is far greater than the supply. Many opportunities exist for graduates in research in universities, in government and in private industry. The extension service is anxious to hire properly trained persons in this field. The industry is seeking properly trained people to fill management positions.

FOR ADVANCED UNDERGRADUATES

PO 401 POULTRY DISEASES 4(3-2) S

The major infectious, noninfectious and parasitic diseases of poultry are studied with respect to economic importance, etiology, susceptibility, dissemination, symptoms and lesions. Emphasis is placed upon practices necessary for the prevention, control and treatment of each disease.

PO 402 COMMERCIAL POULTRY ENTERPRISES 4(3 2) S
Required of technology and business majors in poultry science; elective for others with consent of instructor.

Principles of incubation of chicken and turkey eggs; hatchery management; organization and development of plants for the operation and maintenance of a commercial poultry farm for meat and egg production; study of the types of buildings, equipment and methods of management currently employed by successful poultrymen in North Carolina. Problem.

PO 404 (FS 404) POULTRY PRODUCTS 3(2-3) F
(See food science, page 158.)

PO 415 (ANS 415, NTR 415) COMPARATIVE NUTRITION 3(3-0) F
Prerequisite: CH 220 or CH 221

Fundamentals of animal nutrition, including the classification of nutrients, their requirement and general metabolism by different species for health, maintenance, growth and other productive functions.

PO 490 POULTRY SEMINAR 1(1-0) FS

Current topics and problems relating to poultry science and to the poultry industry are assigned for oral reports and discussion. Required of seniors in poultry science.

FOR GRADUATES AND ADVANCED UNDERGRADUATES

PO 520 (GN 520) POULTRY BREEDING 3(2-2) F
Prerequisite: GN 411

Application of genetic principles to poultry breeding, considering physical traits and physiological characteristics feather patterns, egg production, hatchability, growth, body conformation and utility. Mr. Blow

PO 524 (ZO 524) COMPARATIVE ENDOCRINOLOGY 4(3-3) S
Prerequisite: ZO 414 (BO 414) or ZO 421

Study of the endocrine system with respect to its physiological importance to metabolism, growth and reproduction. Mr. Prince

FOR GRADUATES ONLY

PO 698 SPECIAL PROBLEMS IN POULTRY SCIENCE Maximum 6 FS
Prerequisite: Graduate standing

Specific problems of study are assigned in various phases of poultry science.

Graduate Staff

PO 699 POULTRY RESEARCH Credits Arranged FS

Prerequisite: Graduate standing

A maximum of six credits is allowed towards a master's degree.

Appraisal of present research; critical study of some particular problem involving original investigation. Problems in poultry breeding, nutrition, disease, endocrinology, hematology or microbiology. Graduate Staff

Product Design

GRADUATE FACULTY

Associate Professor VINCENT M. FOOTE, *Acting Head*
Professors: WALTER P. BAERMANN, JOSEPH H. COX, HENRY L. KAMPHOEFNER, DUNCAN R. STUART; *Associate Professors:* GEORGE L. BIRELINE, HARRY A. MACKIE, DON A. MASTERTON; *Assistant Professor:* GENE HEDGE; *Visiting Assistant Professor:* ARMAND V. COOKE

We recognize that, within the present rapid expansion of knowledge, the design capabilities by which man can control his environment have also expanded. It is because of this expanding knowledge and a growing interdisciplinary interaction that the graduate program of the Department of Product Design will encourage participation from qualified students in related fields. By enrolling capable students from allied disciplines who are able to work on comprehensive design teams, problem solutions will be far more substantive. In addition, this form of interdisciplinary team activity will train students to function more effectively in contemporary industrial environments.

The growing affluence of our society has created an expanding need for new products. This coupled with an ever increasing middle class and shorter working hours has substantially broadened the industrial requirements for competent designers; designers who are able to handle the increasing complexities of materials and manufacturing developments, as well as satisfying the physical and psychological needs of the consumer. Industrial expansion has bred new dimensions of competition; competition that demands the consistent reexamination and design of even the most pedestrian products; competition that has overcome the manifestations of conspicuous consumption, which permeated the market the past thirty years, and that now has created a "performance" product market. Only the most broadly educated and talented designers are able to fulfill the needs of this new industrialized society, graduates who will aid in the solution of the numerous human problems that surround us on a regional, national and international scale.

These are the aspirations of the graduate program of the Department of Product of Design.

In order to achieve these ends, it has become necessary for the designer to involve himself in three major design and research activities:

a. Man
b. The Man Production Relationship (or interface)
c. The Product

A great deal of meaningful information has been generated over the last forty years in human behavior. However, little has been done to test and adapt this data to real design problems with adequate controls. Hence the greatest body of available information has never manifested itself in design solutions. This "bridg ing" or applied research will be one of the basic commitments of the graduate program.

The profusion of available new mechanisms has created a dilemma of a different kind. Man finds himself in this last third of the 20th century confronted by a constantly diminishing personal relationship with the artifacts provided him. This has produced another area of concern to product designers—that of the man-product relationship or interface. The students of the graduate program in product design will be asked to consider and test the relationship between their innovations and human responses at all states of product development.

The traditional designers single concern with visual characteristics of a product, therefore, no longer represents the intent or purpose of the Department of Product Design. It is currently felt that the contemporary design should be capable of evolving a significant concept into a solution, such that the final configuration combines unique practicality with lasting beauty. These skills require a greatly expanded knowledge in materials, manufacturing processes, human behavior, communication and systems analysis.

All students with a four year undergraduate degree shall be required to complete a minimum of 48 hours of course work of which approximately 70 percent will be in the major field and the remainder elected from various specialized areas. All students with a five year undergraduate degree shall be required to complete a minimum of 30 hours of course work of which approximately 70 percent will be in the major field and the remainder elected from various specialized areas.

The program of course work to be followed by the student and the terminal project is under the direction of the student's graduate committee. This committee will consist of a minimum of three graduate faculty members, at least two of whom will be from the Department of Product Design and one from the minor discipline. The terminal project shall constitute the final test of the candidate's mastery of his design studies. The project shall be developed in the design studio or special projects framework in the sixth year and shall consist of an in depth investigation of an approved problem which relates product design studies to the student's minor field. Group projects, with a maximum of three students collaborat ing, may be permitted by special arrangement, if the problem to be explored is sufficiently broad or its nature requires a wide range of investigation.

ADMISSION

Applicants for this program may come from the following sources:

1) Graduates of approved schools of product design.
2) Graduates of approved programs of industrial design.
3) Graduates of accredited schools of engineering.
4) Graduates of accredited schools of architecture.

5) Graduates of approved schools of visual design.
6) Under special circumstances, students with degrees in fields other than design. In these latter instances an advisory committee will evaluate the applicant's preparation with regard to design capabilities and professional competence.

In addition, course offerings are available to any graduate student who can demonstrate reasonable competence or equivalent qualifications for prerequisites in the requested courses.

All applicants, in addition to meeting the requirements of the Graduate School, must meet the special requirements of the Department of Product Design with regard to design capabilities and professional competence.

FOR ADVANCED UNDERGRADUATES

PD 400 INTERMEDIATE PRODUCT DESIGN (SERIES) 4(6-3) FS
Prerequisite: DN 202 or equivalent or consent of department

This group of courses shall be concerned with various social/economic age groups, various forms and rates of production, and various natural and synthetic materials.

PD 411, 412 APPLIED PHYSICAL PRINCIPLES 3(2-2) FS
Prerequisite: Intermediate design standing

Various experiments applying physical principles to product design and development.

PD 421, 422 COLLOQUIUM III, IV 1(1-0) FS

Continuation of Colloquium I, II (PD 321, 322), treating various phases of the subject in depth. Special emphasis on communication, communication systems and media of communication. Faculty, guest lecturers, discussion and "field experience." Required selected reading.

PD 431, 432 OFFICE AND INDUSTRIAL PRACTICE I, II 1(1 0) FS

Study of the ethics, organization and procedures of professional product design practice; patent law.

PD 440 INTERMEDIATE VISUAL DESIGN (SERIES) 4(6-3) FS
Prerequisite: DN 202 or equivalent or departmental approval

Intermediate investigations of the visual environment through the agency of various materials and processes leading to professional competence in visual design.

PD 490 INTERMEDIATE SPECIAL PROJECTS (SERIES) 2(1-3) FS

Special projects guided by various faculty specialists involved in areas supplementary to product design and visual design option.

FOR GRADUATES AND ADVANCED UNDERGRADUATES

PD 501, 502 PRODUCT DESIGN V, VI 6(3-12) FS
Prerequisite: PD 400 or graduate standing

PD 501—Unlimited production systems designed with object(s) possibilities produced additively of new synthetic materials utilizing new molecular joining for national class and age groups. PD 502 Unlimited production systems design with object(s) possibilities produced additively of new synthetic materials utilizing new molecular joining for international class and age groups. (Individually selected

problems within interdisciplinary team organizations.) NOTE: It shall be assumed that the program is cumulative and that these statements are problem parameters, exclusive of communication requirements.

PD 511, 512 MATERIALS AND PROCESSES V, VI 2(1 3) FS
Prerequisite: Graduate standing

Advanced studies in mass production processes and their influence on design. Emphasis placed on material search and process selection in relation to cost, function, human factors, form, finishes and joining methods, as indicated by the current design projects in which the students are involved.

PD 532 OFFICE AND INDUSTRIAL PRACTICE 1(1-0) FS
Prerequisite: PD 432 or graduate standing

Advanced studies and procedures of professional product design practice, product and industrial planning and patent law.

PD 541, 542 ADVANCED VISUAL DESIGN I, II 6(3 9) FS
Prerequisites: ARC 400, LAR 400, PD 400 or waiver of prerequisite is at the discretion of the instructor.

Application of previous studies in design and visual communications to a wide variety of visual problems presented by our physical environment.

PD 590, 591 SPECIAL PROJECTS 3(1-6) FS

Special projects of an interdisciplinary nature, guided by various faculty specialists involved in areas supplementary to product design. Emphasis placed on latest technological development of new materials. Also emphasis on concept of new useful designs for the mass market. The production aspects of products such as materials, processes, functions, human factors, sales appeal, finishing and assembly methods and packaging will be stressed in special project designs.

FOR GRADUATES ONLY

PD 601, 602 ADVANCED PRODUCT DESIGN VII, VIII 6(0 18) FS
Prerequisites: PD 501, 502 or graduate standing

Continuation of PD 501, 502 at an advanced level. Unlimited production systems designed with object(s) possibilities produced additively of new synthetic materials utilizing new molecular joining for international class and age groups.

PD 631, 632 ADVANCED CONCEPTS IN PRODUCT ENGINEERING 3(3-0) FS
Prerequisites: PD 502, graduate standing

Group investigation of advanced concepts in product design with emphasis on engineering. Engineering principles play an important role in the design of useful products. The scope of this course will include mass movement of persons as well as the designs of consumer products. The field of transportation and consumer products are fast changing to satisfy the needs of the present and future generations. The product designer is to be made aware of these needs by special investigations into future technologies and future material developments.

Psychology

GRADUATE FACULTY

Professor HOWARD G. MILLER, *Head*
Professors: HAROLD M. CORTER, DONALD W. DREWES, JOSEPH C. JOHNSON, ROBERT E. LUBOW, SLATER E. NEWMAN, RICHARD G. PEARSON; *Professor Emeritus;*

KEY L. BARKLEY; *Adjunct Professor:* RANDALL M. CHAMBERS; *Associate Professors:* JAMES L. COLE, JOSEPH W. CUNNINGHAM, JOHN MAGILL, BRUCE A. NORTON, JOHN L. WASKI, BERT W. WESTBROOK; *Clinical Associate Professors:* ROBERT B. DUKE; *Adjunct Associate Professors:* GILBERT GOTTLIEB, GERALD S. LEVENTHAL; *Assistant Professors:* THOMAS D. GARDNER, THOMAS E. LeVERE, JAMES E. R. LUGINBUHL; *Clinical Assistant Professor:* MARGARET N. UTLEY; *Visiting Assistant Professors:* EUGENE F. MALESKI, RACHEL F. RAWLS; *Adjunct Assistant Professors:* BRENDA C. BALL, RONALD W. OPPENHEIM

ASSOCIATE MEMBER OF THE DEPARTMENT

Associate Professor: STANLEY M. SOLIDAY

The Department of Psychology offers courses of study leading to the Master of Science and Doctor of Philosophy degrees. Specialization in animal behavior, human factors, learning, physiological psychology, social psychology, school psychology and human resource development is available. All courses of study are designed to provide the student with solid grounding in the basic areas of psychology. A course in clinical community psychology is in the process of development.

Specialization in animal behavior, human factors, learning, physiological psychology and social psychology emphasizes the development of proficiency in experimental methodology. Human resource development is concerned with research on human performance in vocational and educational settings. School psychology prepares for professional competence in the practice of school psychology and associated research.

A minimum of 30 semester hours of graduate credit is required for the master's degree. Though no minimum number of additional hours is required for the doctoral degree, the student may expect to take 30 or more additional semester hours of graduate credit. In any case, both for master's and doctoral candidates, the actual graduate program for each student is determined on the basis of his individual needs, interests and accomplishments.

Admission requirements for the beginning graduate student in the Department of Psychology are: satisfactory grades in all undergraduate work and at least a "B" average in undergraduate psychology courses and in the undergraduate major; satisfactory scores on the Graduate Record Examination (including the advanced test in psychology for undergraduate psychology majors, or, for non psychology majors, the advanced test in the undergraduate major) and the Miller Analogies Test; and three satisfactory letters of recommendation in regard to quality of work and character. It is possible to enter the program without undergraduate coursework in psychology but, as a general rule, some preparation in experimental psychology, statistics and mathematics is desirable. Admission requirements for students already possessing the master's degree who wish to obtain the doctorate in psychology are: a minimum of a "B" average in their graduate work and a substantial background in psychology or related fields; satisfactory grades in undergraduate studies; satisfactory scores on the Graduate Record Examination including the advanced test in psychology (if the applicant's master's degree is in a field other than psychology, he should also submit the advanced score in that field and the Miller Analogies Test; and three satisfactory letters of recommendation in regard to quality of work and character.

The physical facilities for the training of graduate students in psychology include laboratories for the study of animal behavior, human learning and cognitive

processes, perceptual and motor skills, environmental stress, social interaction, psychological testing, statistical analysis, psychoacoustics and speech communication.

Basic and applied research projects are supported by the National Institute of Mental Health, the National Institute of Child Health and Human Development, the U. S. Office of Education, the National Science Foundation and the National Aeronautics and Space Administration. The Department of Psychology is closely associated with the Center for Occupational Education, a campus center having responsibility for conducting and coordinating extensive research activities in fields related to occupational education. The Department of Psychology also maintains close ties with Dorothea Dix Hospital, a state mental hospital in Raleigh; with the Rehabilitation Division of the North Carolina Commission for the Blind; with the Division of Research of the North Carolina Department of Mental Health which conducts basic and applied research in fields related to mental health; and with the Highway Safety Research Center at Chapel Hill.

Research and teaching assistantships and fellowships are available to qualified graduate students. The assistantships are usually based on one-third time assignments but are occasionally for one half time.

FOR ADVANCED UNDERGRADUATES

PSY 411 SOCIAL PSYCHOLOGY 3(3-0) S
Prerequisite: PSY 200

The individual in relation to social factors. Socialization, personality development, communication, social conflict and social change. Mr. Luginbuhl

PSY 475 CHILD PSYCHOLOGY 3(3 0) S
Prerequisite: PSY 200 or PSY 304

The development of the individual child of elementary school age will be the inclusive object of study in this course. Emphasis will be placed upon the intellectual, social, emotional and personality development of the child. Physical growth will be emphasized as necessary for an understanding of psychological development.

PSY 476 ADOLESCENT PSYCHOLOGY 2(2-0) FS
Prerequisite: PSY 200 or PSY 304

Nature and source of the problems of adolescents in western culture; emotional, social, intellectual and personality development of adolescents. Usually given as part of student teaching semester.

PSY 491, 492 SEMINAR IN PSYCHOLOGY 3(3 0) FS
Prerequisites: Senior standing, consent of department

This course is designed to provide the undergraduate psychology major with skill in designing and conducting independent research studies; knowledge of sources and skill in locating information pertaining to behavior; knowledge of major trends in selected areas of study; knowledge of the research techniques available to the psychologist; knowledge of the organization of psychology as a profession; and an understanding of the code of ethics for psychologists.

PSY 493 SPECIAL TOPICS IN PSYCHOLOGY 1-6 FS
Prerequisite: Consent of instructor

An individual study course. Any undergraduate student may suggest an activity (review of literature on a topic, designing and conducting an experiment or

survey, etc.) to a professor. After discussing the activity, if both student and professor agree that it is worthwhile and that the student is competent to undertake it, and if the professor is willing to direct the activity, then the student will enroll in PSY 493 the following semester.

PSY 495 HUMAN RESOURCE DEVELOPMENT PRACTICUM 8(0 8) FS
Prerequisites: Junior standing, PSY HRD option; PSY 350, PSY 351, PSY 352; SP 231

This course is designed to provide the student with an opportunity to acquire field experience in the use of skills acquired during the Skill Semester. The student will spend at least a full semester working in a selected off campus center. In addition to practicing his skills, the student will be able to experience real-world problems in context, and thus can arrange his later course work around subjects applicable to the solution of those problems.

FOR GRADUATES AND ADVANCED UNDERGRADUATES

PSY 500 PERCEPTION 3(2-2) S
Prerequisite: Graduate standing

The first half of the course will be a summary and analysis of the major classes of variables affecting perception. The data will be examined in the context of the development of theories of perception with emphasis on the general problem of scientific method and theory construction as well as the specific content of perceptual theory. The second half of the course will summarize and analyze the major modes of thinking and the variables affecting the thinking process. Special emphasis will be placed on the relationship between perception and thinking, and a number of the theories of thinking will be evaluated.
Messrs. Lubow, Newman

PSY 502 PHYSIOLOGICAL PSYCHOLOGY 3(3-0) F
Prerequisite: Twelve hours of psychology, including PSY 200, PSY 300, PSY 310

A survey of the physiological bases of behavior including the study of coordination, sensory processes, brain functions, emotions and motivation. Mr. LeVere

PSY 503 (ZO 503) COMPARATIVE PSYCHOLOGY 3(3-0) S
Prerequisites: PSY 310 and BS 100 or consent of instructor

Covers the history of the study of the comparative behavior of organisms; methodological and theoretical problems peculiar to comparative psychology, with emphasis on the ontogeny and evolution of behavior in vertebrate animals.
Mr. Gottlieb

PSY 504 ADVANCED EDUCATIONAL PSYCHOLOGY 3(3-0) FS
Prerequisite: Six hours of psychology

A critical appraisal of current psychological findings that are relevant to educational practice and theory. Mr. Johnson

PSY 505 HISTORY AND SYSTEMS OF PSYCHOLOGY 3(3-0) S
Prerequisites: PSY 200, PSY 300, PSY 310, PSY 320 or consent of instructor or graduate standing

The aim of this course is to acquaint students with the history of psychology and psychological systems and to give students some practice in taking different approaches to a particular problem area.

PSY 510 LEARNING AND MOTIVATION 3(3-0) F
Prerequisite: Graduate standing

A systematic analysis of some of the major classes of variables determining

behavioral change. Learning variables are analyzed within their primary experimental setting, and emphasis is upon the diversity of the functions governing behavior change rather than upon the development of some comprehensive theory. Both learning and motivational variables are examined as they contribute to changes in performance within the experimental setting.

Messrs. Cole, Newman, Pearson

PSY 511 ADVANCED SOCIAL PSYCHOLOGY 3(3-0) S
Prerequisite: Graduate standing or consent of instructor

A survey of theory and research in social psychology through reading and discussion of primary source materials. In addition, the course will deal with issues of methodology, ethical questions in social psychological research and application of research findings to the world at large. Mr. Luginbuhl

PSY 514 LOGICAL FOUNDATIONS OF BEHAVIORAL ANALYSIS 3(3-0) F
Prerequisite: Graduate standing in psychology

An analysis of fundamental considerations involved in the formulation and verification of theories of behavior. Such topics as operationalism, formalism, reductionism, logical analysis and the nature of truth in empirical sciences will be introduced and related to research in various areas of psychological interest. The objectives are to provide insight into the nature of scientific research, to foster the ability to derive empirical hypotheses, to develop facility in designing experimental tests of hypotheses, and to promote effective writing and speaking about psychological theory and experimentation. Mr. Drewes

PSY 520 COGNITIVE PROCESSES 3(2-2) F
Prerequisite: Graduate standing

This course will emphasize the results from research on a number of complex processes (e.g. remembering, concept learning, acquisition and use of language) and the theories that have been proposed to explain these results. Mr. Newman

PSY 530 ABNORMAL PSYCHOLOGY 3(3 0) S
Prerequisites: PSY 200, PSY 302

A study of the causes, symptomatic behavior and treatment of the major personaility disturbances. Emphasis will be placed on theory, experimental psychopathology and preventive measures. Mr. Duke, Miss Utley

PSY 531 (ED 531) MENTAL DEFICIENCY 3(3 0) S Sum.
(See education, page 130.)

PSY 532 (ED 532) PSYCHOLOGICAL ASPECTS OF EXCEPTIONALITY 3(3-0) S Sum.
Prerequisite: Consent of instructor

This course is designed to give consideration to effects of severe deficiency (sensory, physical, mental, etc.) arising from any causes at any stage of life; the personal and social ramifications of these; and possible courses of intervention; as well as utilization of psychological theory and clinical information in interpreting probable implications. Research findings related to sensory deprivation, research needs and possible research projects will be discussed. Mrs. Rawls

PSY 535 TESTS AND MEASUREMENTS 3(3-0) FS
Prerequisite: Six hours of psychology

A study of the principles of psychological testing including norms and units of measurement, elementary statistical concepts, reliability and validity. In addition, some attention is devoted to the major types of available tests such as general intellectual development, tests of separate abilities, achievement tests, measures of personality and interest inventories. Mr. Westbrook

PSY 540 (IE 540) HUMAN FACTORS IN SYSTEMS DESIGN 3(3 0) S
(See industrial engineering, page 192.)

PSY 550 MENTAL HYGIENE IN TEACHING 3(3-0) F
Prerequisite: Six hours of psychology

PSY 565 ORGANIZATIONAL PSYCHOLOGY 3(3 0) S
Prerequisite: Nine hours of psychology

A study of the application of behavioral science, particularly psychology and social psychology, to organizational and management problems. Mr. Miller

PSY 570 THEORIES OF PERSONALITY 3(3-0) F
Prerequisite: Graduate standing

A review of theories of personality, with emphasis on research, application in psychotherapy and measurement, and principles involved in similarities and differences among them. Mr. Corter

PSY 571 INDIVIDUAL INTELLIGENCE MEASUREMENT 3(3-0) S
Prerequisite: PSY 520

A practicum in individual intelligence testing with emphasis on the Wechsler-Bellevue, Stanford-Binet, report writing and case studies. Mr. Maleski

PSY 576 DEVELOPMENTAL PSYCHOLOGY 3(3 0) F
Prerequisite: Nine hours of psychology, including PSY 475 or PSY 476

A survey of the role of growth and development in human behavior, particularly during the child and adolescent periods. This course will pay particular attention to basic principles and theories in the area of developmental psychology.
Messrs. Gardner, Johnson

PSY 578 INDIVIDUAL DIFFERENCES 3(3-0) FS
Prerequisite: Six hours of psychology

Nature, extent and practical implications of individual differences and individual variation. Graduate Staff

PSY 591 AREA SEMINAR IN CLINICAL-COMMUNITY PSYCHOLOGY 1-3 FS
Prerequisite: Consent of instructor (6 maximum)

The following topics will be dealt with: (1) the development of clinical-community psychology as an area of study, (2) methods of inquiry, (3) contemporary issues, (4) ethical questions, (5) relationship to other areas within psychology.
Graduate Staff

PSY 592 AREA SEMINAR IN EXPERIMENTAL PSYCHOLOGY 1-3 FS
Prerequisite: Graduate standing in psychology (6 maximum)

The following topics will be dealt with: (1) the development of experimental psychology as an area of inquiry, (2) methods of inquiry, (3) contemporary issues, (4) ethical questions, (5) relationship to other areas within psychology.
Graduate Staff

PSY 593 AREA SEMINAR IN HUMAN FACTORS ENGINEERING 1-2 FS
Prerequisite: Graduate standing (3 maximum)

Introduction to human factors engineering as an area of study; historical aspects; contemporary issues; ethical questions; overview of campus research, facilities and courses in the area; consideration of information sources, financial support for research proposals and employment opportunities. Mr. Pearson

PSY 594 AREA SEMINAR IN HUMAN RESOURCES DEVELOPMENT 1 3 FS
Prerequisite: Consent of instructor (6 maximum)

The following topics will be dealt with: (1) human resources development as an area of inquiry, (2) methods of inquiry, (3) contemporary issues, (4) ethical questions, (5) relationship to other areas within psychology. Graduate Staff

PSY 595 AREA SEMINAR IN SCHOOL PSYCHOLOGY 1-3 FS
Prerequisite: Graduate standing (6 maximum)

The following topics will be dealt with: (1) the development of school psychology as a professional area, (2) methods of inquiry, (3) scientific and theoretical bases, (4) contemporary issues, (5) ethical questions, (6) relationship to other areas within psychology. Graduate Staff

PSY 596 AREA SEMINAR IN SOCIAL PSYCHOLOGY 1-3 FS
Prerequisite: Graduate standing (6 maximum)

This course will deal with the following topics: (1) a survey of areas within social psychology, (2) methods of inquiry, (3) contemporary issues, (4) ethical questions, (5) the relation of social psychology to other branches of psychology, to other disciplines, and to society and its problems. Graduate Staff

PSY 599 RESEARCH PROBLEMS IN PSYCHOLOGY Credits Arranged FS
Prerequisite: Consent of instructor

Research project for graduate students supervised by members of the graduate faculty. Research to be elected on basis of interest of student, and is not to be part of thesis or dissertation research. Graduate Staff

FOR GRADUATES ONLY

PSY 602 PHYSIOLOGICAL PSYCHOLOGY 3(3 0) S
Prerequisites: PSY 502 and/or consent of instructor

Psychology 602 is the sequel to Psychology 502 and will concentrate on relating the neuroanatomy and neurophysiology studied in PSY 502 to overt observable behaviors such as sleep waking, motivation-emotion, and reflexive and learned behaviors. Mr. LeVere

PSY 603 VERBAL LEARNING AND VERBAL BEHAVIOR 3(3-0) S
Prerequisites: PSY 510, PSY 514

This course will provide opportunity for exploration in depth of verbal learning research studying acquisition, transfer and retention and the theories that have been proposed to explain the results of this research. Implications of findings from verbal-learning research for understanding concept learning, problem-solving and the acquisition and use of language will also be explored. Mr. Newman

PSY 604 CLASSICAL CONDITIONING 3(3-0) F
Prerequisites: PSY 510, PSY 514

The origins of classical conditioning theory and methodology will be traced from Sechenov, Bechterev and Pavlov through the recent Russian and American work. The influence of the classical conditioning paradigm on American psychology as expressed in learning theory and the conditioning therapies will be examined.
Mr. Lubow

PSY 605 INSTRUMENTAL LEARNING 3(3-0) S
Prerequisites: PSY 510, PSY 514

A systematic analysis of various experimental techniques and alternative data

languages for the study of instrumental learning. Primary orientation will be upon what is happening in the experimental situation rather than upon theoretical explanations of the data. Special problems, for example, discrimination, avoidance, chaining and reinforcement schedules, will be studied in depth. Various models for description of the data will be compared with special emphasis upon mathematical learning models. Mr. Cole

PSY 607 ADVANCED INDUSTRIAL PSYCHOLOGY I 3(3-0) S
Prerequisite: Nine hours of psychology and statistics or concurrent with statistics

Application of scientific methods to the measurement and understanding of industrial behavior. Messrs. Drewes, Miller

PSY 608 ADVANCED INDUSTRIAL PSYCHOLOGY II 3(3-0) F
Prerequisite: PSY 607

Application of scientific methods to the measurement and understanding of industrial behavior. Messrs. Drewes, Miller

PSY 610 THEORIES OF LEARNING 3(3-0) F or S
Prerequisites: PSY 510, PSY 514

The objectives of this course are to promote learning of the theories currently used to explain how learning and forgetting occur so that testable consequences of these theories can be derived and so that the theories and their testable consequences are capably written and spoken about. Messrs. Cole, Lubow, Newman

PSY 611 SOCIAL PSYCHOLOGY: SMALL GROUPS RESEARCH 3(3-0) S
Prerequisite: PSY 511

Factors that determine the pattern of interaction within small groups will be examined. Some factors to be considered are social norms, roles, communication networks, power and status hierarchies and types of leadership. Conformity behavior, affiliative behavior and techniques of interpersonal influence will also be analyzed. The role of interpersonal perception and individual differences in social behavior will be examined. Mr. Luginbuhl

PSY 635 PSYCHOLOGICAL MEASUREMENT 3(3-0) F
Prerequisites: ST 507, ST 511 or equivalent, 12 hours of psychology

Theory of psychological measurement. Statistical problems and techniques in test construction. Messrs. Cunningham, Drewes

PSY 640 (IE 640) SKILLED OPERATOR PERFORMANCE 3(3-0) F

(See industrial engineering, page 193.)

PSY 672 PERSONALITY MEASUREMENT 3(2-3) FS
Prerequisites: PSY 570, PSY 571

Theory and practicum in individual personality testing of children and adults with emphasis on projective techniques, other personality measures, report writing and case studies. Mr. Corter

PSY 674 PSYCHOLOGICAL INTERVENTION I 3(2-2) F
Prerequisite: PSY 672

This course is designed to examine theories, research, techniques, ethics and professional responsibilities related to approaches to psychological intervention. Types of psychological intervention to be studied will include behavior modification, milieu approaches, crisis intervention techniques and group process methods, in addition to more intensive relationship approaches. A close integration of experi-

ences, content and supervision will be emphasized in a variety of professional settings with a wide range of personal problems and age groups. Mr. Norton

PSY 675 PSYCHOLOGICAL INTERVENTION II 3(2-2) S
Prerequisite: PSY 674

The primary purpose of this course is to provide students opportunities to acquire information, conceptual frameworks, interpersonal skills and a sense of ethical responsibility, all of which are basic to their further development as practicing psychologists. A major effort in the course is made to help the student increase his interpersonal skills as a means of promoting the psychological growth and effectiveness of others. Mr. Norton

PSY 690 SEMINAR IN INDUSTRIAL PSYCHOLOGY 3(3-0) FS

Scientific articles, analysis of experimental designs in industrial psychology and study of special problems of interest to graduate students in industrial psychology. Messrs. Drewes, Miller

PSY 691 SPECIAL TOPICS IN PSYCHOLOGY 1 3 FS
Prerequisite: Graduate standing, consent of instructor

Course will provide opportunity for exploration in depth of advanced topical areas which, because of their degree of specialization, are not generally involved in other courses, for example multivariate methodology in psychology, computer simulation, mathematical model building. Some new 600 level courses will first be offered under this title during the developmental phase and as such may involve lectures and/or laboratories. Graduate Staff

PSY 693 PSYCHOLOGICAL CLINIC PRACTICUM Maximum 12 FS
Prerequisite: Nine hours in psychology

Clinical participation in interviewing, counseling, psychotherapy and administration of psychological tests. Practicum to be concerned with adults and children. Mr. Corter

PSY 696 ADVANCED PROBLEMS IN PERCEPTION 3(2-2) F
Prerequisites: PSY 500, PSY 514

Advanced topics in perception will be the subject matter of this course. Topics will include a survey and analysis of contemporary trends in perceptual research and theory. Mr. Lubow

PSY 697 (ED 697) ADVANCED SEMINAR IN RESEARCH DESIGN 3(3-0) S

(See education, page 132.)

PSY 699 THESIS AND DISSERTATION RESEARCH Credits Arranged FS
Prerequisites: Graduate standing, consent of instructor

Individual or group research problems; a maximum of six credits is allowed toward the master's degree, but any number toward the Ph.D. degree. Graduate Staff

Recreation Resources Administration

GRADUATE FACULTY

Professor THOMAS I. HINES, *Head*
Professor: WILLIAM E. SMITH; *Adjunct Professor:* THOMAS H. RIPLEY; *Associate*

Professors: GORDON A. HAMMON, LATHAM L. MILLER, ROBERT J. STERNLOFF; *Assistant Professor:* M. ROGER WARREN, JR.

The Department of Recreation Resources Administration offers programs of study leading to the Master of Science and Master of Recreation Resources degrees. The programs are based on an interdisciplinary approach and are designed to meet the problems and opportunities posed by changing social forces which affect the recreation profession. Students pursuing these degrees will have an opportunity to develop an understanding of the relationship between recreation and disciplines such as forestry, wildlife management, horticulture, landscape design, conservation, economics, politics, sociology and anthropology.

The Master of Science degree is designed to enhance in advanced students scholarly development and a more adequate comprehension of the requirements and responsibilities essential for independent research. A student will be required to complete a minimum of 30 hours of graduate work. The program will consist of a major and minor field of study. The minor may be concentrated wholly in a different discipline or may consist of courses selected from the offering of two departments. In either case, the minor field must constitute a unified pattern and must contribute to the student's education in the major field. A high degree of flexibility is maintained to permit each student's program to be structured to meet his needs.

Each candidate for the Master of Science degree will be required to complete a thesis representing an original investigation as a part of the minimum requirements for the degree.

The Master of Recreation Resources degree is designed for students who are interested in the more advanced applications of administrative principles in specialized areas of the recreation field. Students for this degree will usually terminate their graduate program upon completion of the master's degree. Requirements for the Master of Recreation Resources degree include a minimum of 36 hours of course work, and in lieu of a thesis, the student will be required to complete a departmental course in research and a problem report.

FOR ADVANCED UNDERGRADUATES

RRA 440 RECREATION RESOURCE INVENTORY AND PLANNING 3(2 2) FS
Prerequisite: RRA 241

This course is an examination of concepts and principles which provide a basis for recreation resource quantification and allocation and factors which are involved in inventorying the physical properties and associated intangible values of the recreation resource on extensive wildlands. The resource planning function is studied as an essential component of the managerial process. Mr. Hammon

RRA 441 RECREATION RESOURCE DEVELOPMENT 3(3-0) FS
Prerequisite: RRA 241

The recreation resource manager's role in situations typical of the federal, state and private sectors is examined. Categories of information are reviewed as to their significance in the decision-making and problem solving process. Competent information systems are examined. Mr. Hammon

RRA 442 WILDLAND RECREATION ENVIRONMENTS 3(2-3) FS
Prerequisite: Junior standing

A study of environmental modifications and resource developments required to support recreation use. Factors affecting the selection of sites for development are

related to resource planning functions. Site planning procedures provide a basis for managerial review. Natural history interpretation is an element of resource management. Concepts of natural beauty are reviewed, and approaches to the preserva tion of amenities through modified methods of commercial product management are explored. Mr. Warren

RRA 451 FACILITY AND SITE PLANNING 3(0-6)FS
Prerequisites: RRA 215 and RRA 216

This course includes the history of park and recreation facility development and trends in recreation facility planning. Emphasis is placed upon the planning principles involved in the design and layout of recreation areas and recreation buildings. Field trips will enable the student to see the various types of recreation facilities. Mr. Stott

RRA 453 ADMINISTRATIVE POLICIES AND PROCEDURES 3(3-0) FS
Prerequisite: RRA 359

This course is involved with: the internal organization of the recreation and park department; the administrative process; legislation and legal foundations; boards and commissions; personnel practices and policies; office management; public relations. Mr. Sternloff

RRA 454 RECREATION AND PARK FINANCE 3(3-0)
Prerequisites: Six hours recreation resources administration, senior standing

This course is involved with: recreation and park fiscal administration; sources of finance for current and capital expenditures; revenue activities; financial planning; budgeting; expenditure policies; accounting; auditing and planning for recreation and park services. Mr. Hines

RRA 491 SPECIAL PROBLEMS IN RECREATION 3(2-2) FS
Prerequisite: Consent of department

A survey of specific problems in recreation. Aims to develop critical analysis. Forms a basis for the organization of research projects, for the compilation and organization of material in a functional relationship and for the foundation of policies. Follows the seminar procedure. Staff

FOR GRADUATES AND ADVANCED UNDERGRADUATES

RRA 500 THEORIES OF LEISURE AND RECREATION 3(3-0)
Prerequisite: Nine hours of RRA courses

This course presents an analysis of leisure and recreation and a study of their origin and development as revealed by man's behavioral patterns. An interpretation is made of the influence and social significance of leisure and recreation concepts on contemporary American culture and their implications on future recreation thought and action. Mr. Warren

RRA 501 THEORY DEVELOPMENT IN RECREATION RESEARCH 4(3-2)
Prerequisites: ST 311 and SOC 416

This course reviews the historical emphasis of recreation research and examines various approaches to research design and model building. The philosophy of social scientific investigation, and possible application of existing behavioral theory to recreation research are examined with a special emphasis on efforts to develop theory useful in explaining use of leisure time. Staff

FOR GRADUATES ONLY

RRA 691 SEMINAR IN RECREATION ADMINISTRATIVE POLICIES 2(0-4)
Prerequisite: RRA 501 or equivalent

As an advance course in administrative principles, students will do individual and group research, under supervision, in specific administrative categories of study in the field of recreation. Independent study and research will be required of the student who must develop written and oral presentations for critical analyses by graduate students and faculty. Mr. Hines

RRA 692 ADVANCED PROBLEMS IN RECREATION Credits Arranged
Prerequisite: Twelve hours of RRA courses

Directed research in a specialized phase of recreation other than a thesis problem. Staff

RRA 699 RESEARCH IN RECREATION Credits Arranged
Prerequisite: Twelve hours of RRA courses

Original research preliminary to writing a master's thesis. Staff

Sociology and Anthropology

GRADUATE FACULTY

Professor SELZ C. MAYO *Head*
Professors: ROBERT J. DOLAN, LAWRENCE W. DRABICK, GLENN C. MCCANN, *Graduate Administrator*, C. PAUL MARSH, JAMES N. YOUNG; *Extension Professor:* JAMES D. GEORGE; *Professor Emeritus:* C. HORACE HAMILTON; *Associate Professors:* A. CLARKE DAVIS, CHARLES V. MERCER, HORACE D. RAWLS, MAN M. SAWHNEY, ODELL UZZELL; *Visiting Associate Professor:* HAROLD D. HOLDER; *Assistant Professors:* ROBERT C. BRISSON, WILLIAM B. CLIFFORD, II, CLEBURN G. DAWSON, GARY L. FAULKNER, R. DAVID MUSTIAN, ELIZABETH M. SUVAL; *Extension Assistant Professor:* CHARLES E. LEWIS

The Department of Sociology and Anthropology offers a program of study leading to the Doctor of Philosophy degree with a major in sociology. The department also has programs leading to the Master of Sociology degree (nonthesis) with a major in sociology and the Master of Science degree with a major in rural sociology. The curriculum includes several major areas of interest: community and area development; planned change; social change and development and deviancy and rehabilitation. Other programs of specialization may be developed in terms of the needs and interests of the individual student. The core program includes sociological theory, research methods and quantitative analysis. Special attention is given in the curriculum to the development of sociological skills involved in an understanding of social factors and public policies as they affect regional, national and international development.

Allied and supplemental fields of study include statistics, history, politics, economics, psychology, education and some other related fields.

The increasing emphasis being placed on change—growth and development—in the region, the nation and throughout the world has resulted in an increasing demand for well-trained workers in sociology and anthropology. Graduates of the department with a master's degree have opportunities for work in industry, federal

and state agencies, and to teach, particularly in the rapidly expanding community college and junior college systems.

Doctor of Philosophy graduates have opportunities for employment as teachers and research workers in colleges and universities throughout the nation. Many also find excellent opportunities in various agencies of federal and state government whether they are involved in research or educational work. International development agencies provide employment opportunities for some graduates.

Departmental offices are located on the third and second floors of the 1911 Building. Graduate students on assistantships and fellowships are usually provided with office space and equipment. Computational facilities are available for students whose research problems involve extensive analyses of data as well as for those students who want to learn to do their own programming. Computing facilities available to students and faculty in the department are described on page 16.

The University of North Carolina at Chapel Hill and Duke University at Durham are less than 30 miles away. Some students, particularly those in the doctoral program, frequently take courses at these universities. Facilities are available for commuting.

The department has the responsibility for a state-wide program in community and area development. This provides an excellent laboratory for both personal observation and research, and graduate students are encouraged to use the facilities and other resources of this program in extended education.

FOR ADVANCED UNDERGRADUATES

ANT 410 THEORIES OF CULTURE 3(3-0) FS
Prerequisites: Six hours sociology, ANT 252 or equivalent

The study of major anthropological theories of culture with intensive analysis of their application.

ANT 416 FIELD METHODS IN CULTURAL ANTHROPOLOGY 3(3-0) FS
Prerequisite: Six hours anthropology

(1) To provide a systematic experience with anthropological field techniques, i.e., community mapping, household census, kinship analysis, life-history recording, participant observation, inventory of material culture, child rearing observations. (2) To furnish an opportunity to use conventional anthropological field tools, i.e., tape recorder, motion picture camera, still camera, field work journal, unstructured interview. (3) Through textbooks and supplementary reading, students will become familiar with anthropologists' reports of their own field methods and the problems they encountered.

SOC 401 HUMAN RELATIONS IN INDUSTRIAL SOCIETY 3(3 0) FS
Prerequisites: Senior standing, consent of instructor

Studies in the sociology of occupations, professions and work, with special attention to human relations in industrial plants and other work situations.

SOC 402 URBAN SOCIOLOGY 3(3-0) FS
Prerequisite: SOC 202 or consent of instructor

A study of the factors in the growth of cities; the relationship between the design of cities and their social organization; detailed analysis of new developments in the serving of human needs. City and regional planning.

SOC 405 Social Work I 3(3-0) F
Prerequisites: SOC 202, consent of instructor

A course designed to acquaint students with the various types of public and voluntary social work and with remedial and preventive programs in applied sociology, social psychiatry, health, public welfare and recreation.

SOC 406 Social Work II 3(2 2) S
Prerequisites: Six hours sociology, consent of instructor

The subjects covered include emergence and present status of social work as a profession, roles, role conflict and the generic base of methods in social work. Attention is focused on casework, group work and community organization. Some time is devoted to research efforts and to modes of administration. Each student is given an opportunity to participate in the current operations of one agency in the community.

SOC 411 Community Relationships 3(3-0) FS
Prerequisites: SOC 202, consent of instructor

A survey of the institutions, organizations and agencies found in modern communities; social problems and conditions with which they deal; their interrelationship and the trend toward overall planning.

SOC 414 Social Structure 3(3-0) FS
Prerequisites: Six hours sociology, consent of instructor

Studies of the major social institutions and systems of stratification; the organi zation of social studies of the major social institutions and systems of stratification; the organization of social systems as, for example, religion, education and government; the functions of such structural components as age and sex groups, vocational and professional groups, and social classes.

SOC 416 Research Methods 3(3-0) FS
Prerequisites: Six hours of sociology and ST 311 or nine hours of sociology

An analysis of the principal methods of social research; the development of experiments; schedules and questionnaires; the measurement of behavior.

SOC 425 Juvenile Delinquency 3(3-0) FS
Prerequisite: SOC 306 or six hours social science

The epidemiology of juvenile delinquency is explored. Descriptive typologies are compared. Theories of causation are developed with emphasis on social institutions, peer groups and socialization processes. Procedures for enforcement, adjudication and correction of young offenders are investigated. Strategies for prevention of delinquency are examined. Opportunities for observation and participation in agency operations are included.

SOC 451 Population and Public Affairs 3(3-0) FS
Prerequisite: SOC 202 or equivalent

Growth rates, changing composition and residential redistribution are studied in relation to public issues and planning. Attention is given to the ways in which population data are utilized by public agencies in program and policy formulation. Analysis encompasses new problems and socioeconomic situations which develop as a consequence of the dynamic nature of population changes in contemporary society.

SOC 490, 491 Senior Seminar 3(3-0) FS
Prerequisite: Consent of department

This course is of an integrative nature giving the student an opportunity to synthesize knowledge, theory and methods learned in earlier courses and to conduct original explorations in areas of special interest.

SOC 494, 495 (EC 494, 495; PS 494, 495) URBAN SEMINAR 3(3-0) FS

(See politics, page 265.)

SOC 498 SPECIAL TOPICS IN SOCIOLOGY 1 6 FS
Prerequisite: Six hours sociology above the freshman level

The student will make a detailed investigation of a special topic in sociology or anthropology. The topic and mode of study will be determined by the faculty member(s) in consultation with the head of the Department of Sociology and Anthropology.

FOR GRADUATES AND ADVANCED UNDERGRADUATES

ANT 512 APPLIED ANTHROPOLOGY 3(3 0) FS
Prerequisite: ANT 252 or consent of instructor

The course includes a review of the historical development of applied anthropology and a study of anthropology as applied in government, industry, community development, education and medicine. The processes of culture change are analyzed in terms of the application of anthropological techniques to programs of developmental change. Graduate Staff

SOC 501 (ED 501) LEADERSHIP 3(3 0) FS Sum.
Prerequisite: SOC 202 or equivalent

A study of leadership in various fields of American life; analysis of the various factors associated with leadership; techniques of leadership. Particular attention is given to recreational, scientific and executive leadership procedures. Mr. Young

SOC 502 SOCIETY, CULTURE AND PERSONALITY 3(3-0) FS
Prerequisite: SOC 202 or equivalent

Human personality is studied from its origins in primary groups through its development in secondary contacts and its ultimate integration with social norms. While comparative anthropological materials will be drawn upon, emphasis is placed upon the normal personality and the adjustment of the individual to our society and to our culture. The dynamics of personality and character structure are analyzed in terms of the general culture patterns and social institutions of society. Mr. Rawls

SOC 503 CONTEMPORARY SOCIOLOGY 3(3 0) FS
Prerequisite: Graduate standing

The basic purpose of this course is to provide the student with an overview of the current status of sociological theory and research. It will introduce the student to contemporary sociological thinking and research and provide a base for further graduate training in the discipline. Graduate Staff

SOC 504 EDUCATION IN MODERN SOCIETY 3(3 0) FS
Prerequisites: SOC 202, SOC 301, or equivalent

An analysis of education using basic sociological concepts. Varying emphases will be placed upon the historical development of education in the United States, cross-cultural comparisons of educational structure and function, professionalization of educators, investigation of the ecological factors affecting education, effects of group processes upon learning, and the effects of social processes and changes upon the educational institution. Mr. Drabick

SOC 505 THE SOCIOLOGY OF REHABILITATION I 3(3 0) FS
Prerequisite: Graduate standing and/or consent of instructor

The area of disability and handicap is introduced from a conceptual and theoretical standpoint. Sociological and social-psychological aspects of handicaps, the

rehabilitation processes, and rehabilitative organizations are stressed throughout. Particular attention is given to rehabilitation of the sociology of work in the rehabilitation processes. Sociocultural factors in disability and handicap (residence, social class, family relationships, etc.) are analyzed in depth. Mr. Rawls

SOC 506 THE SOCIOLOGY OF REHABILITATION II 3(3-0) S
Prerequisite: Graduate standing and/or consent of instructor

Students will be expected to engage in individual research projects on a specific handicap, a rehabilitation process or a rehabilitative agency or subagency. An attempt will be made through lectures and discussions to give the student perspective concerning the actual work of rehabilitation in process while he is pursuing his specialized interest. Emphasis will be placed on sociological methods and techniques applicable to the study of the above aspects of social behavior. Mr. Rawls

SOC 509 POPULATION PROBLEMS 3(3-0)F
Prerequisite: SOC 202 or equivalent

A study of population growth, rates of change and distribution. Considerable attention is given to the functional roles of population, i.e., age, sex, race, residence, occupation, marital status and education. The dynamic aspects of population are stressed: fertility, mortality and migration. Population policy is analyzed in relation to national and international goals. A world view is stressed throughout.
Mr. Clifford

SOC 510 INDUSTRIAL SOCIOLOGY 3(3-0) FS
Prerequisite: SOC 202 or equivalent

Industrial relations are analyzed as group behavior with a complex and dynamic network of rights, obligations, sentiments and rules. This social system is viewed as an interdependent part of total community life. The background and functioning of industrialism are studied as social and cultural phenomena. Specific social problems of industry are analyzed. Mr. Mercer

SOC 511 SOCIOLOGICAL THEORY 3(3-0) FS
Prerequisites Six hours in sociology and graduate standing or consent of instructor

Study of the interpendence of theory and method; the major theoretical and methodological systems; and examination of selected cases of research in which theory and method are classically combined. Mr. Sawhney

SOC 512 FAMILY ANALYSIS 3(3-0) F
Prerequisite: SOC 202 or equivalent

This course examines the basic theoretical and methodological framework in sociology within which contemporary family research is conducted. Mr. Mercer

SOC 513 (ED 513) COMMUNITY ORGANIZATION 3(3-0) F
Prerequisite: SOC 202 or equivalent

Community organization is viewed as a process of bringing about desirable changes in community life. Community needs and resources available to meet these needs are studied. Democratic processes in community action and principles of community organization are stressed, along with techniques and procedures. The roles of leaders, both lay and professional, in community development are analyzed.
Graduate Staff

SOC 514 DEVELOPING SOCIETIES 3(3-0) S
Prerequisite: Six hours of sociology or anthropology or graduate standing

The purpose of this course is to define the major problems posed for development

sociology and to explore the social barriers and theoretical solutions for development set forth with special regard to the newly-developing countries. Significant past strategies will be reviewed as well as main themes in current development schemes. Finally, some untested strategies for the future will be proposed for discussion. These problems will be examined in their national and international contexts.
Mr. Moxley

SOC 515 DEVIANT BEHAVIOR 3(3 0) S
Prerequisite: Six hours of sociology or anthropology or graduate standing

Many topics include: the inevitability of deviance and its social utility; cross-cultural variations in appearance and behavioral cues for labeling the deviate; descriptive and explanatory approaches to kinds and amounts of deviance in contemporary American society; social change, anomie and social disorganization theories; the process of stigmatization; formal and informal societal responses to deviance and the deviate; social action implications. There is no other graduate course presently offered in deviate behavior. Mrs. Suval

SOC 523 SOCIOLOGICAL ANALYSIS OF AGRICULTURE LAND TENURE SYSTEMS 3(3-0) F
Prerequisite: Three hours of sociology

A systematic sociological analysis of the major agricultural and land-tenure systems of the world with major emphasis on the problems of family farm owner ship and tenancy in the United States. Graduate Staff

SOC 533 THEORY OF HUMAN COMMUNICATION BEHAVIOR 3(3 0) FS
Prerequisites: Six hours sociology or social psychology and graduate standing

This course is organized to introduce students to the behavioral science approach to an understanding of human communication. Communication is treated as a basic social psychological process in which communication events are analyzed in terms of their effects on individual, interpersonal and group behavior. Students will survey the theory, research methods and empirical findings developed in the emerging field of communication. Communication behavior is treated as a mediating mecha nism in social interaction. Graduate Staff

SOC 534 AGRICULTURAL ORGANIZATIONS AND MOVEMENTS 3(3 0) S
Prerequisites: Three hours of sociology, American history, American government or a related social science or consent of department

A history of agricultural organizations and movements in the United States and Canada principally since 1865, emphasizing the Grange, the Farmers' Alliance, the Populist revolt, the Farmers' Union, the Farm Bureau, the Equity societies, the Nonpartisan League, cooperative marketing, government programs and present problems. Graduate Staff

SOC 541 SOCIAL SYSTEMS AND PLANNED CHANGE 3(3 0) FS
Prerequisite: Three hours of sociology

An examination of social systems within the framework of both functional theory and conflict theory with particular emphasis upon system change and the planning of social change. Mr. Marsh

SOC 555 SOCIAL STRATIFICATION 3(3-0) FS
Prerequisite: Six hours of sociology

In this course the student would be introduced to the theoretical background, the methodological approaches and the analysis of the consequences of systems of

stratification. Emphasis would be on the static and dynamic qualities of stratification systems in rural and urban industrial societies as well as the effects of these systems on relations within and between societies. Particular attention will be paid to the integrative and divisive quality of stratification as it is expressed in life styles, world views, etc. Mr. Davis

SOC 560 RACIAL AND CULTURAL CONTACTS 3(3 0) S
Prerequisite: Six hours of sociology or consent of instructor

The course is organized in three sequential sections, the first of which deals with intergroup relations as a legitimate concern of the social sciences. The second consists of an appraisal of cross-cultural data that have been drawn from a variety of situations wherein race and ethnicity figure in a significant manner. Finally, an effort is made to interpret data by delineating observable patterns, trends and relationships. Graduate Staff

SOC 565 SOCIOLOGY AND GENERAL SYSTEMS THEORY 3(3 0) F
Prerequisites: Six hours of sociology, one course in statistics

In this course the student will study the basis of general systems theory and review its application in the field of sociology. Emphasis is placed on the philo sophical nature of systems theory and its potential as an alternative conceptualization to mechanistic and organismic models. Attention is given to the underlying basis of systems theory; to cybernetics as models of change and control; learning and equilibrium; to information theory as models of choice and selection; to decision theory; and to game theory. Mr. Holder

SOC 574 (EC 574) ECONOMICS OF POPULATION 3(3-0) FS

(See economics, page 123.)

SOC 590 APPLIED RESEARCH 3(3 0) FS
Prerequisite: SOC 202 or equivalent

A study of the research process with particular emphasis upon its application of action problems. The development of research design to meet action research needs receives special attention. Graduate Staff

SOC 591 SPECIAL TOPICS IN SOCIOLOGY 6(6-0) FS
Prerequisite: Consent of instructor

An examination of current problems in sociology organized on a lecture-discussion basis. The content of the course will vary as changing conditions require the use of new approaches to deal with the emerging problems. Graduate Staff

FOR GRADUATES ONLY

SOC 611 RESEARCH METHODS IN SOCIOLOGY 3(3-0) F
Prerequisites: SOC 416, ST 311 or equivalent

Designed to give the student a mature insight into the nature of scientific research in sociology. Assesses the nature and purpose of research designs, the interrelationship of theory and research, the use of selected techniques and their relation to research designs, and the use of modern tabulation equipment in research. Mr. McCann

SOC 613 THEORY OF MASS COMMUNICATION 3(3-0) S
Prerequisite: SOC 533 or equivalent

This course provides the advanced student in the social sciences with an opportunity to examine the emerging body of theory and research in the field of mass communications. Course content will treat (1) the systems character of mass com-

munication, (2) social communication at the individual and group level, (3) persuasive communication and social control, (4) communication and opinion change, and (5) communication and societal development. In addition to the theoretical and methodological underpinnings drawn from the behavioral sciences, the course will examine contributions from the communication arts and applied communications.
Graduate Staff

SOC 621 SOCIAL PSYCHOLOGY 3(3-0) S
Prerequisite: Six hours of sociology

The objective of this course is to present the major ideas of social psychology in the context of the theoretical orientations from which they have emerged. The nature and role of theory in social psychology are examined. The social psychologies of various theorists are then examined in terms of their particular approaches including the Gestalt, Field, Role, Psychoanalytic and Reinforcement orientations and combinations of these. Mr. McCann

SOC 631 POPULATION ANALYSIS 3(3 0) S
Prerequisite: Six hours of sociology

Methods of describing, analyzing and presenting data on human populations: distribution, characteristics, natural increase, migration and trends in relation to resources. Mr. Mustian

SOC 632 SOCIOLOGY OF THE FAMILY 3(3 0) S
Prerequisite: Six hours of sociology

Emphasis is placed on the development of an adequate sociological frame of reference for family analysis; on discovering both the uniquely cultural and common human aspects of the family by means of cross-cultural comparisons; on historical explanations for variability in American families with special concern for the family; and on analyzing patterns of family stability and effectiveness.
Graduate Staff

SOC 633 THE COMMUNITY 3(3-0) S
Prerequisite: Six hours of sociology

The community is viewed in sociological perspective as a functioning entity. A method of analysis is presented and applied to eight "dimensions," with emphasis on the unique types of understanding to be derived from measuring each dimension. Finally, the effect of change on community integration and development is analyzed.
Messrs. Brisson, Mayo

SOC 641 STATISTICS IN SOCIOLOGY 3(3 0) S
Prerequisite: ST 513 or equivalent

The application of statistical methods of sociological research. Emphasis on selecting appropriate models, instruments and techniques for the more frequently encountered problems and forms of data. Graduate Staff

SOC 652 COMPARATIVE SOCIETIES 3(3-0) S
Prerequisite: Six hours of sociology

Sociological analysis of societies around the world with particular reference to North and South America. Special emphasis is given to cultural and physical setting, population composition, levels of living, relationship of the people to the land, structure and function of the major institutions and forces making for change.
Graduate Staff

SOC 653 THEORY AND DEVELOPMENT OF SOCIOLOGY 3(3-0) S
Prerequisites: SOC 511, consent of instructor

Detailed analysis of methodological and substantive problems in utilizing

sociological theories in varied areas, and an examination of events and trends in the development of sociology. Graduate Staff

SOC 671 SOCIAL DEMOGRAPHY 3(3-0) S
Prerequisites: Graduate standing, SOC 509 or SOC 631 or equivalents

The basic purpose of this course is to develop on the part of the student an appreciation of the sociological variables capable of being used in demographic research and to provide an overview of the current substantive knowledge concerning social and demographic relationships. Attention will be given to the interrelationships between demographic systems, social action systems and social aggregate systems. Mr. Clifford

SOC 690 SEMINAR Credits Arranged FS

Appraisal of current literature; presentation of research papers by students; progress reports on departmental research; review of developing research methods and plans; reports from scientific meetings and conferences; other professional matters. Graduate Staff

SOC 699 RESEARCH IN SOCIOLOGY Credits Arranged FS
Prerequisite: Consent of chairman of graduate study committee

Planning and execution of research, and preparation of manuscript under supervision of graduate committee. Graduate Staff

Soil Science

GRADUATE FACULTY

Professor CHARLES B. MCCANTS, *Head*
Professors: WILLIAM V. BARTHOLOMEW, STANLEY W. BUOL, MAURICE G. COOK, CHARLES B. DAVEY, JAMES W. FITTS, WILLIAM A. JACKSON, EUGENE J. KAMPRATH, J. FULTON LUTZ, RICHARD J. VOLK, JEROME B. WEBER, STERLING B. WEED, WILLIAM G. WOLTZ, WILLIAM W. WOODHOUSE, JR.; *Extension Professor:* JACK V. BAIRD; *Professor USDA:* RAYMOND B. DANIELS; *Adjunct Professors:* LOUIS J. METZ, JAMES M. SPAIN; *Associate Professors:* FRED R. COX, GEORGE A. CUMMINGS, JAMES W. GILLIAM, ROBERT E. MCCOLLUM; *Visiting Associate Professor:* ARVEL H. HUNTER; *Visiting Associate Professors AID:* JAMES L. WALKER, DONOVAN L. WAUGH; *Adjunct Associate Professor* CAROL G. WELLS; *Extension Associate Professor:* JOSEPH A. PHILLIPS; *Assistant Professors:* CLIFFORD K. MARTIN, CHARLES D. RAPER, JR., PEDRO A. SANCHEZ; *Extension Assistant Professor:* DAVID L. TERRY

The Department of Soil Science offers programs leading to the degrees of Master of Soil Science, Master of Science and Doctor of Philosophy with specialization in soil chemistry, soil fertility, soil physics, soil genesis, soil microbiology or soil conservation. The Master of Agronomy professional degree is also available.

Modern facilities are provided in Williams Hall for graduate teaching and research activities. Office and laboratory space is assigned each student. Facilities for graduate research include radioactive and stable isotope laboratories containing automatic recording scalers and liquid scintillation apparatus, a mass spectrometer, amino acid analyzer, X-ray diffraction apparatus with fluorescence, differential thermal analysis, infrared spectrophotometer, atomic absorption spectrophotometer,

polarizing microscope, high-speed centrifuges, thin-sectioning apparatus and other modern equipment. Photomicrographic equipment is available for photographing thin sections and microorganisms.

Service laboratories for soil and plant analyses are available as well as special preparation rooms for soil and plant samples. Greenhouses, growth chambers and a Phytotron situated near William Hall are easily accessible for controlled plant studies. Sites for field experiments are available on the 16 research farms and four experimental forests owned or operated by the state. Located throughout North Carolina, the farms and forests include a wide variety of soil and climate conditions. One of the largest soil testing laboratories in the United States is operated by the North Carolina Department of Agriculture in Raleigh. Special studies on various problems of soil testing can be made in conjunction with this laboratory.

Strong supporting departments greatly increase the graduate student's opportunities for a broad and thorough training. Included among those departments in which graduate students in soil science work cooperatively or obtain instruction are: crop science, biological and agricultural engineering, botany, chemistry, economics, forestry, geology, mathematics, plant pathology, physics and statistics.

FOR GRADUATES AND ADVANCED UNDERGRADUATES

SSC 511 SOIL PHYSICS 4(3-3)F
Prerequisites: PY 212, SSC 200

Physical constitution and analyses; soil structure, soil water, soil air and soil temperature in relation to plant growth. Mr. Lutz

SSC 520 SOIL AND PLANT ANALYSIS 3(1-6) S
Prerequisites: PY 212; CH 315; at least three soils courses including SSC 341, or consent of instructor

Theory and advanced principles of the utilization of chemical instruments to aid research on the heterogeneous systems of soils and plants. Mr. Gilliam

SSC 522 SOIL CHEMISTRY 3(3-0) S
Prerequisites: SSC 200, one year of general inorganic chemistry

A consideration of the chemical and colloidal properties of clay and soil systems, including ion exchange and retention, soil solution reactions, solvation of clays and electrokinetic properties of clay-water systems. Mr. Weed

SSC 532 (MB 532) SOIL MICROBIOLOGY 3(3-0) S
Prerequisites: CH 220, MB 401

The more important microbiological processes that occur in soils; decomposition of organic materials, ammonification, nitrification and nitrogen fixation.
Mr. Wollum

SSC 541 SOIL FERTILITY 3(3-0) F
Prerequisite: SSC 341

Soil conditions affecting plant growth and the chemistry of soil and fertilizer interrelationships. Factors affecting the availability of nutrients. Methods of measuring nutrient availability. Mr. Kamprath

SSC 551 SOIL MORPHOLOGY, GENESIS AND CLASSIFICATION 3(3-0) F
Prerequisites: GY 120, SSC 200, SSC 341

Morphology: Study of concepts of soil horizons and soil profiles and chemical, physical and mineralogical parameters useful in characterizing them. Genesis:

Critical study of soil forming factors and processes. Classification: Critical evaluation of historical development and present concepts of soil taxonomy with particular reference to great soil groups as well as discussion of logical basis of soil classification. Mr. Buol

SSC 553 SOIL MINERALOGY 3(2-3) F
Prerequisites: SSC 200, SSC 341, GY 331 or equivalent

Composition, structure, classification, identification, origin, occurrence and significance of soil minerals with emphasis on primary weatherable silicates, layer silicate clays and sesquioxides. Mr. Cook

SSC 560 ADVANCED SOIL MANAGEMENT 3(3-0) Sum.
Prerequisites: SSC 200, SSC 341

Field studies of selected soil series in the coastal plain, Piedmont and mountain areas of North Carolina. Discussion of management practices that should be associated with the various soils under different types of farming. (Offered summer 1971 and alternate years.) Messrs. Kamprath, Cook, Phillips

SSC 590 SPECIAL PROBLEMS Credits Arranged FS
Prerequisite: SSC 200

Special problems in various phases of soils. Emphasis will be placed on review of recent and current research. Graduate Staff

FOR GRADUATES ONLY

SSC 614 (CS 614, HS 614) HERBICIDE BEHAVIOR IN PLANTS AND SOILS 3(3-0) F

(See crop science, page 113.)

SSC 622 SOIL PHYSICAL CHEMISTRY 3(3-0) S
Prerequisites: SSC 511, SSC 553, CH 433

An examination in depth of current ideas in the field. Topics will include double-layer theory, molecular absorption, ion exchange, diffusion of ions in soil-water systems, and relations between clay mineral structures and their chemical properties. Mr. Weed

SSC 632 (MB 632) ECOLOGY AND FUNCTIONS OF SOIL MICROORGANISMS 3(3-0) S
Prerequisites: MB 401, SSC 532 (MB 532) or equivalent

A comprehensive examination of theories and concepts relative to ecology and functions of soil microorganisms. Topics include relationships of microbes to their environments, adaptive mechanisms, microbial processes in soil organic matter formation and degradation, and function of organic matter in soil systems. Subject emphasis will be determined by class interests and by current literature. (Offered 1972-73 and alternate years.) Messrs. Bartholomew, Davey

SSC 651 PEDOLOGY 3(3-0) F
Prerequisites: SSC 522, SSC 511; SSC 551 or equivalent

A critical study of current theories and concepts in soil genesis and morphology; detailed study of soil taxonomy. Topics include weathering and clay mineral genesis as related to soil morphology and genesis, functional analyses of soil genesis, properties of and processes responsible for soil profiles formed under various sets of soil-forming factors, classification theory and logic as applied to soil classification, structure of soil classification schemes. Any of these topics may be emphasized, according to student interests. (Offered 1971-72 and alternate years.)
Mr. McCracken

SSC 671 (BAE 671) THEORY OF DRAINAGE: SATURATED FLOW 3(3 0) Alternate F

(See biological and agricultural engineering, page 78.)

SSC 672 SOIL PROPERTIES AND PLANT DEVELOPMENT 3(3-0) S
Prerequisites: BCH 551, SSC 522 or equivalent

A detailed examination of the effects of soil factors in the development of crop plants. Segments of the course will treat soil transformation processes of both organic and inorganic constituents, concepts of nutrient availability and the relation of plant development indices to specific soil properties. (Offered 1971-72 and alternate years.) Mr. Jackson

SSC 674 (BAE 674) THEORY OF DRAINAGE: UNSATURATED FLOW 3(3-0) Alternate S

(See biological and agricultural engineering, page 78.)

SSC 690 SEMINAR 1(1-0) FS
Prerequisite: Graduate standing in soil science

A maximum of two semester hours is allowed toward the master's degree, but any number toward the doctorate.

Scientific articles, progress reports in research and special problems of interest to soil scientists reviewed and discussed. Graduate Staff

SSC 693 COLLOQUIUM IN SOIL SCIENCE Credits Arranged FS
Prerequisite: Graduate standing in soil science

Seminar-type discussions and lectures on specialized and advanced topics in soil science. Graduate Staff

SSC 699 RESEARCH Credits Arranged FS
Prerequisite: Graduate standing in soil science

A maximum of six semester hours is allowed toward the master's degree, but any number toward the doctorate. Graduate Staff

Statistics

GRADUATE FACULTY

Professor DAVID D. MASON, *Head*

Professors: C. CLARK COCKERHAM, ARNOLD H. E. GRANDAGE, ROBERT J. HADER, DON W. HAYNE, HENRY L. LUCAS, JR., FRANCIS E. MCVAY, ROBERT J. MONROE, LAWRENCE A. NELSON, CHARLES H. PROCTOR, CHARLES P. QUESENBERRY, JOHN O. RAWLINGS, DON L. RIDGEWAY, JACKSON A. RIGNEY, ROBERT G. D. STEEL, *Graduate Administrator*, HUBERTUS R. VAN DER VAART, T. DUDLEY WALLACE, OSCAR WESLER; *Adjunct Professors:* ALVA L. FINKNER, DANIEL G. HORVITZ, JAY T. WAKELEY; *Professor Emeritus:* GERTRUDE M. COX; *Associate Professors:* BIBHUTI B. BHATTACHARYYA, FRANCIS G. GIESBRECHT, HARVEY J. GOLD, MAJOR M. GOODMAN, WILLIAM L. HAFLEY, ALLISON R. MANSON, JOHN L. WASIK; *Associate Professor USFS:* BENEE F. SWINDEL; *Adjunct Associate Professor:* DAVID W. GAYLOR; *Assistant Professors:* THOMAS M. GERIG, ARDELL C. LINNERUD, DONALD C. MARTIN, MARY B. WILLIAMS; *Visiting Assistant Professors:* PETER M. BURROWS, A. RONALD GALLANT; *Adjunct Assistant Professor:* DAVID L. BAYLESS; *Research Associate:* ROBERT P. GECKLER

The Department of Statistics offers work leading to the Master of Science, Master of Statistics (nonthesis), Master of Biomathematics (nonthesis) and Doctor of Philosophy degrees. This department has a working arrangement with the Department of Biostatistics in the University of North Carolina's School of Public Health at Chapel Hill, whereby graduate students can major in (experimental) statistics and minor in the Division of Health Affairs. The Department of Statistics maintains a close liaison with the Department of (Mathematical) Statistics at Chapel Hill in order to supplement the offerings in statistical theory. (See University of North Carolina at Chapel Hill courses listed below.) Introductory courses in the three departments are coordinated so that it is easy for a beginning statistics graduate student to transfer from one institution of the University to another. The three departments are affiliated with the Institute of Statistics (see page 14). Some doctoral theses in (experimental) statistics are directed by members of the graduate faculty of the two statistics departments at Chapel Hill.

Members of the department conduct research in biomathematics, nonlinear systems, time series and spectral analysis, operations research, probability and stochastic processes, nonparametric inference, the development of statistical theory and techniques of design and analysis for surveys and experiments, and the development of physical and biological stochastic models. At least one staff member consults with researchers in each of the following fields and conducts his own research on statistical problems which are encountered: the various agricultural sciences, quantitative genetics, wildlife science (game and fish), industrial development and engineering, physical sciences, and social sciences and economics.

A graduate student who majors in (experimental) statistics may specialize in any one of these fields, with his minor in the associated departments, or with a strong mathematical background he may prefer to minor in mathematics or mathematical statistics. The department has cooperated with eight other departments at Raleigh and Chapel Hill to develop a strong minor program in operations research at both the master's and doctoral levels. Details regarding the operations research graduate program are presented on page 242. For the graduate student who wishes to minor in statistics, the department has developed a curriculum tailored to his needs. Many employers are offering added inducements for research personnel who have such a minor. The department cooperates with other graduate departments in order to provide the type of courses needed for their students and to provide a staff to participate in their graduate programs.

A program of training in biomathematics at the doctoral and postdoctoral levels is available in the Department of Statistics. This program requires that the student become well grounded in four areas—mathematics, statistics, physical science and some phase of biology. Fellowships and assistantships are available for doctoral students and several fellowships for postdoctorals. Mathematical biology and related areas are now developing rapidly and there is much opportunity for properly trained people.

In addition to its consulting services, the department provides computer programming and other assistance to the Agricultural Experiment Station staff in close cooperation with the campus Computing Center. This work is currently augmented by a computer facility grant from the National Institutes of Health. The department also provides a desk calculator computing service. It furnishes several federal agencies, other states and private concerns with research and consulting services on a contract basis. This work supplies live problems on which graduate students may acquire experience and maturity.

The Department of Statistics is located in a new building convenient to classroom and central library facilities. Ample space for graduate students is provided

adjacent to faculty offices. A well-equipped desk computing laboratory is conveniently located in the graduate student area.

The Computing Center is equipped with an IBM System 360-Model 40 computer which serves in a dual capacity simultaneously as a stand alone computer, and as a teleprocessing terminal unit to the Triangle Universities Computation Center IBM System 370-Model 165 computer. While this is the only high-speed terminal currently planned for the campus, several medium and low-speed terminals have been or will be installed. Currently, the department has access to a Data 100-Model 78 computer which is also used as a medium-speed terminal to the TUCC IBM-Model 165. The department also has three teletypewriter terminals (low-speed) to the TUCC Model 165. All teletypewriter terminals are interactive and may use the Conversational Program System (CPS). One of the terminals has the APL language capability. Also, one low-speed terminal is equipped with an X-Y plotter. In addition, the Biomathematics Signal Processing Laboratory is currently equipped with a hybrid computer, the Ambilog 200. Funds are now available to greatly increase the capability of this facility.

The department has approximately 20 graduate fellowships and assistantships at stipends adjusted to the previous training and experience of the recipients. Included among these have been industrial fellowships, National Institutes of Health fellowships in biomathematics and National Defense Education Act fellowships. Students who have a major in an applied field who have a minimum of one year of calculus, or students who have a major in statistics or mathematics are encouraged to apply for these fellowships and assistantships. Students who have no advanced calculus or matrix algebra are advised that their program may be somewhat lengthened as a consequence. If a graduate assistant has a satisfactory course record, he can complete the requirements for the master's degree in two years (in less time if he takes courses during the summer). A graduate assistant with a master's degree in statistics can complete the requirements for the doctorate in two years. Graduate fellows may be able to complete the requirements in somewhat less time.

Most fields of research, development, production and distribution are seeking persons trained in statistical theory and methods. The demand is equally strong from universities, agricultural and engineering experimental stations, national defense agencies, other federal agencies and a wide variety of industrial concerns. There is a need for experimental statisticians with the master's degree as well as for those with the doctorate.

North Carolina State University is represented on the Committee on Statistics of the Southern Regional Education Board. This committee sponsors a continuing series of graduate summer sessions. In 1972, the host institution is Rice University and the 1973 session is tentatively scheduled at Florida State University. Each of the sponsoring institutions will accept the credits earned by students in the summer session as residence credit. Information regarding these courses may be obtained from the Department of Statistics or the Dean of the Graduate School.

FOR ADVANCED UNDERGRADUATES

ST 421, 422 INTRODUCTION TO MATHEMATICAL STATISTICS 3(3-0) FS
Prerequisite: MA 202 or MA 212 or MA 232

Elementary mathematical statistics primarily for students not intending to take

further work in theoretical statistics. Includes introduction to probability, common theoretical distributions, moments, moment generating functions, sampling distributions (F, t, chi square), elementary estimation, hypothesis testing concepts, decision theory concepts and elements of general linear model theory. Staff

FOR GRADUATES AND ADVANCED UNDERGRADUATES

ST 501, 502 BASIC STATISTICAL ANALYSIS 3(3-0) FS
Prerequisite: ST 311 or equivalent or graduate standing

Basic concepts of statistics; random variables, distributions, statistical measures, estimation, tests of significance, analysis of variance, elementary design and sampling, factorial experiments, multiple regression, analysis of discrete data and other topics. Intended primarily for statistics majors and Ph.D. minors and not intended as a service course for other departments. Mr. Steel

ST 507 STATISTICS FOR THE BEHAVIORAL SCIENCES I 3(3 0) F

The purpose of this course is to provide a general introduction to descriptive and inferential statistics. Attention will be paid to investigating the role of statistics in behavioral science research as well as presenting the techniques and principles for summarizing data. A basic introduction to inferential statistics will be made with an emphasis on the concepts of hypothesis testing and decision making. The principles and methods will be illustrated by examples and problems from the behavioral science fields. Mr. Wasik

ST 508 STATISTICS FOR THE BEHAVIORAL SCIENCES II 3(3 0) S
Prerequisite: ST 507 or consent of instructor

The purpose of this course is to provide further consideration of the use of advanced statistical techniques used in decision making in behavioral science research. Attention will be paid to hypothesis testing and analysis of variance procedures used in the design of experiments. A part of the course will be devoted to topics relating to least squares and multiple regression analysis. Mr. Wasik

ST 511 EXPERIMENTAL STATISTICS FOR BIOLOGICAL SCIENCES I 3(3-0) FS
Prerequisite: ST 311 or graduate standing

Basic concepts of statistical models and use of samples; variation, statistical measures, distributions, tests of significance, analysis of variance and elementary experimental design, regression and correlation, chi square. Staff

ST 512 EXPERIMENTAL STATISTICS FOR BIOLOGICAL SCIENCES II 3(3-0) FS
Prerequisite: ST 511 or equivalent

Covariance, multiple regression, concepts of experimental design, factorial experiments, individual degrees of freedom, confounded factorial and split-plot designs. Staff

ST 513 EXPERIMENTAL STATISTICS FOR SOCIAL SCIENCES I 3(3-0) F
Prerequisite: ST 311 or graduate standing

Basic concepts in collection and analysis of data. Variability of sample data, distributions, confidence limits, chi-square, t-test, analysis of variance, regression, correlation, analytic and descriptive surveys, experimental designs. Mr. McVay

ST 514 EXPERIMENTAL STATISTICS FOR SOCIAL SCIENCES II 3(3-0) S
Prerequisite: ST 513 or equivalent

Extension of basic statistical concepts to social experiments and surveys; sampling from finite populations and estimating using unrestricted, stratified,

systematic and multistage selections; analysis of variance continued; multiple regression; covariance; experimental designs. Mr. Proctor

ST 515, 516 EXPERIMENTAL STATISTICS FOR ENGINEERS 3(3-0) FS
Prerequisite: ST 361 or graduate standing

General statistical concepts and techniques useful to research workers in engi neering, textiles, wood technology, etc. Probability, distributions, measurement of precision, simple and multiple regression, tests of significance, analysis of variance, enumeration data, sensitivity data, life-testing experiments and experimental designs. Mr. Hader

ST 517 APPLIED LEAST SQUARES 3(3-0) F
Prerequisite: ST 502 or equivalent

Use of least squares estimation in developing numerical descriptions with linear models. Regression, analysis of variance and covariance are considered in a unified manner that does not require an extensive statistical background. Emphasis is placed on the application of these techniques to experimental situations and in broadening the range of problems to which they can be applied (particularly in terms of unequal numbers). A computer will be used for some assigned problems such as matrix inversion. Staff

ST 521 STATISTICAL THEORY I 3(2 2) F
Corequisite: MA 581 for statisticians and MA 405 or permission of instructor

Discussion of the use of statistics as illustrated by an example, pointing out the need for a probabilistic framework. The probability tools for statistics: description of discrete and absolutely continuous distributions, expected values, moments, moment generating functions, transformation of random variables, marginal and conditional distributions, independence, order statistics, multivariate distributions, concept of random sample, derivation of many sampling distributions.
Mr. van der Vaart

ST 522 STATISTICAL THEORY II 3(2 2) S
Prerequisite: ST 521
Corequisite: MA 581 (a continuation of MA 581 in fall semester)

General framework for statistical inference. Point estimators: biased and unbiased, minimum variance unbiased, least mean square error, maximum likelihood and least squares, asymptotic properties. Interval estimators and tests of hypoth eses: confidence intervals, power functions, Neyman-Pearson lemma, likelihood ratio tests, unbiasedness, efficiency and sufficiency. Mr. van der Vaart

ST 531 DESIGN OF EXPERIMENTS 3(3-0) F
Prerequisite: ST 502 or equivalent

Review of completely randomized, randomized complete block and Latin square designs, and the basic concepts in the techniques of experimental design. Designs and analysis methods in factorial experiments, confounded factorials, response surface methodology, change over design, split-plot experiments and incomplete block designs. Examples will be used to illustrate application and analysis of these designs. Mr. Monroe

ST 541 (MA 541) THEORY OF PROBABILITY I 3(3-0) F

(See mathematics, page 213.)

ST 542 (MA 542) THEORY OF PROBABILITY II 3(3-0) S

(See mathematics, page 213.)

ST 552 BASIC THEORY OF LEAST SQUARES AND VARIANCE COMPONENTS 3(2-2) FS
Prerequisites: MA 405, ST 521
Corequisite: ST 522

Theory of least squares; multiple regression; analysis of variance and covariance; experimental design models; factorial experiments; variance component models.
Staff

ST 561 (EC 561) INTERMEDIATE ECONOMETRICS 3(3 0)S

(See economics, page 123.)

ST 571 (BMA 571, MA 571) BIOMATHEMATICS I 3(3 0) F

(See biomathematics, page 80.)

ST 572 (BMA 572, MA 572) BIOMATHEMATICS II 3(3-0) S

(See biomathematics, page 81.)

ST 581 INTRODUCTION TO NONPARAMETRIC STATISTICS 3(3-0) F
Prerequisite: ST 522

This course will treat both theoretical and methodological material relevant to inference problems arising when sampling is from a parent family that is not assumed to have a particular functional form. Most of the course will be devoted to inference problems for the absolutely continuous family of distributions. (Offered fall 1972 and alternate years.) Mr. Quesenberry

ST 583 INTRODUCTION TO STATISTICAL DECISION THEORY 3(3-0) F
Prerequisite: ST 522

The theory of statistical inference will be discussed from a unified decision theoretic point of view and its relationship with the zero-sum two person game will be studied. Detailed attention will be paid to the development of techniques of statistical analysis using Bayesian approach. The major emphasis in the course will be directed towards the solution of problems using decision theoretic concepts. (Offered fall 1973 and alternate years.) Mr. Bhattacharyya

ST 591 SPECIAL PROBLEMS 1-3 FS

Development of techniques for specialized cases, particularly in connection with thesis and practical consulting problems. Staff

FOR GRADUATES ONLY

ST 606 (MA 606, OR 606) MATHEMATICAL PROGRAMMING II 3(3-0) S
Prerequisite: IE 505 (MA 505, OR 505)

This course is intended for those who desire to study linear and nonlinear programming from an advanced mathematical point of view. Special attention will be paid to the theoretical and computational aspects of current research problems in the field of mathematical programming, including linear programming and game theory, theory of graphs, discrete linear programming, linear programming under uncertainty and nonlinear programming. Mr. Bhattacharyya

ST 613 TIME SERIES ANALYSIS I 3(3-0) S
Prerequisite: ST 552

Statistical analysis of realizations of second-order stationary random processes, and mathematical specifications of the underlying processes, with emphasis throughout on the spectrum. Discussions of applications are given to illustrate the

theory and methods. Topics include second-order stationary parent sequences, correlation analysis, autoregressive series, moving averages, hidden periodicities models, spectral analysis, estimation of the correlogram and the coefficients of autoregressive schemes, the periodogram, estimation of the spectral density; serial correlation theory, goodness-of fit tests. Staff

ST 614 TIME SERIES ANALYSIS II 3(3-0) F
Prerequisites: ST 542 (MA 542), ST 613

Cross-covariance analysis of two time series, cross-spectral analysis of two time series, estimation of co-spectral density, quadrature-spectral density, coherence and phase, interpretations and applications of coherence analysis, detection and estimation of periodicities in variances of time series, spectral representation theory for second order stationary processes, further discussion of spectral estimation.
Staff

ST 617, 618 (MA 617, 618) MEASURE THEORY AND ADVANCED PROBABILITY 3(3-0) FS
Prerequisites: MA 426; ST 521 or MA 541 (ST 541) or equivalent

Modern measure and integration theory in abstract spaces, probability measures, random variables and expectations, conditional probability and conditional expectations, distribution functions, characteristic functions, modes of convergence, weak and strong laws of large numbers, central limit theorems and other limit laws, introduction to stochastic processes. Messrs. Bhattacharyya, Wesler

ST 619 (MA 619) TOPICS IN ADVANCED PROBABILITY 3(3 0) Sum.
Prerequisites: ST 617, 618 (MA 617, 618)

Characteristic functions, infinitely divisible and stable laws, factorizations of probability distributions, laws of iterated logarithm, random walks, fluctuation theory, martingales, ergodic theory, Markov processes, the Poisson process, further topics in stochastic processes, applications. Mr. Wesler

ST 621 STATISTICS IN ANIMAL SCIENCE 3(3 0) F
Prerequisite: ST 502 or equivalent

Sources and magnitudes of errors in experiments with animals, experimental designs and methods of analysis adapted to specific types of animal research; relative efficiency of alternate designs, amount of data required for specified accuracy, student reports on selected topics. (Offered fall 1973 and alternate years.)
Mr. Lucas

ST 622 (ANS 622) PRINCIPLES OF BIOLOGICAL ASSAYS 3(3-0) S

(See animal science, page 68.)

ST 623 STATISTICS IN PLANT SCIENCE 3(3-0) F
Prerequisite: ST 502 or equivalent

Principles and techniques of planning, establishing and executing field and greenhouse experiments. Size, shape and orientation of plots; border effects; selection of experimental material; estimation of size of experiments for specified accuracy; scoring and subjective tests; subsampling plots and yields for laboratory analysis. Mr. Nelson

ST 626 (GN 626) STATISTICAL CONCEPTS IN GENETICS 3(3-0) S
Prerequisite: GN 506
Corequisite: ST 502 or equivalent

Factors bearing on rates of change in population means and variances, with special reference to cultivated plants and domestic animals; selection, inbreeding

magnitude and nature of genotypic and nongenotypic variability; experimental and statistical approaches in the analysis of quantitative inheritance. (Offered spring 1972 and alternate years.) Mr. Cockerham

ST 631 THEORY OF SAMPLING APPLIED TO SURVEY DESIGN 3(3-0) F
Prerequisites: ST 422; ST 502, or equivalent

Principles for interpretation and design of sample surveys. Biases, variances and costs of estimators. Comparisons among simple random sample, ratio estimation, stratification, varying probabilities of selection, multi-stage, systematic and cluster sampling, double sampling. Response errors. Mr. Proctor

ST 637 ADVANCED STATISTICAL INFERENCE 3(3-0) S
Prerequisites: ST 522, ST 617 (MA 617)

This course will treat the classical areas of statistical inference, estimation and hypothesis testing, at the measure theoretic level. Emphasis will be upon treatment of these areas in depth. Mr. Quesenberry

ST 651 (EC 651) ECONOMETRICS 3(3-0) F

(See economics, page 126.)

ST 652 (EC 652) TOPICS IN ECONOMETRICS 3(3-0) S

(See economics, page 126.)

ST 671 ADVANCED ANALYSIS OF VARIANCE AND VARIANCE COMPONENTS 3(3-0) S
Prerequisite: ST 502 or equivalent, ST 552

Expected mean squares, estimation of means, confidence limits, exact and approximate tests of hypotheses for balanced and unbalanced nested, crossed and mixed classifications with random, finite and fixed effects. Estimation of variance components and designs for estimating variance components. Heterogeneity, non-normality, correlated errors and transformations. Mr. Gaylor

ST 672 SPECIAL ADVANCED TOPICS IN STATISTICAL ANALYSIS 3(3-0) F
Prerequisite: ST 502 or equivalent; ST 552

Enumeration data; covariance; nonlinear models; discriminant functions and other multivariate techniques. (Offered fall 1972 and alternate years.) Mr. Monroe

ST 674 ADVANCED TOPICS IN CONSTRUCTION AND ANALYSIS OF EXPERIMENTAL DESIGNS 3(3-0) S
Prerequisites: ST 502 or equivalent; ST 552

Interblock analysis of incomplete block designs, partially balanced designs, confounding, data collected at several places and times, multiple factor designs, change-over-trials, analysis of groups of means. Mr. Manson

ST 682 STATISTICAL ANALYSIS FOR LINEAR MODELS 3(3-0) F
Prerequisites: ST 502 or equivalent, ST 552

Review of basic least squares, partitioning sums of squares, weighted least squares; regression coefficients as random variables; models with redundancies, use of generalized inverses; models with restrictions; applications to disproportionate data, incomplete blocks designs and covariance analysis; arithmetic items; application to nonlinear models. Mr. Gerig

ST 691 ADVANCED SPECIAL PROBLEMS 1-3 FS
Prerequisites: ST 502 or equivalent; ST 552

Any new advance in the field of statistics which can be presented in lecture series as unique opportunities arise. Graduate Staff, Visiting Professors

ST 694 SEMINAR 1(1-0) FS

A maximum of two semester hours is allowed toward the master's degree, but any number toward the doctorate. Graduate Staff

ST 699 RESEARCH Credits Arranged FS

A maximum of nine semester hours is allowed toward the Master of Science degree; no limitation on semester hours in doctorate programs. Graduate Staff

UNIVERSITY OF NORTH CAROLINA AT CHAPEL HILL STATISTICS COURSES

U.N.C. ST 133 INTRODUCTION TO TIME SERIES ANALYSIS 3(3-0) FS
Prerequisite: U.N.C. ST 102 or U.N.C. ST 127

Topics chosen from: Time series data analysis. Fitting parametric models, such as regression-autoregression models to time series. Spectrum analysis. Filtering.
Messrs. Cleveland, Wegman

U.N.C. ST 150 ANALYSIS OF VARIANCE WITH APPLICATION TO EXPERIMENTAL DESIGNS 3(3 0) S
Corequisite: U.N.C. ST 135

Linear estimation. Gauss Markoff theorem. Sums of squares. Analysis of variance and generalized t and F tests. Intrablock analysis of incomplete block designs. Balanced, lattice and Latin square designs. Mr. Chakravarti

U.N.C. ST 170 ORDER STATISTICS 3(3-0) S
Prerequisite: U.N.C. ST 127

Distribution and moments of order statistics. Estimation of location and scale parameters, censoring. Robust estimation. Short-cut procedures. Treatment of outliers. Extreme-value theory. (Offered 1971-1972 and alternate years.) Mr. David

U.N.C. ST 210 DESIGN AND ANALYSIS OF EXPERIMENTS 3(3-0) F
Prerequisites: U.N.C. ST 102 and U.N.C. ST 150

The principles of the design and analysis of experiments. Randomization, replication, local control. Randomized blocks. Latin and Graeco Latin squares, factorial experiments. Confounding, fractional factorials, split plots, recent developments. Mr. Johnson

U.N.C. ST 220 THEORY OF ESTIMATION AND HYPOTHESIS TESTING 4(4-0) F
Prerequisites: U.N.C. ST 132, U.N.C. ST. 135

Bayes procedures for estimation and testing. Minimax procedures. Unbiased estimators. Unbiased tests and similar tests. Invariant procedures. Sufficient statistics. Confidence sets. Large sample theory. Mr. Hoeffding

U.N.C. ST 221 SEQUENTIAL ANALYSIS 3(3 0) F
Prerequisites: U.N.C. ST 132, U.N.C. ST 135

Hypothesis testing and estimation when the sample size depends on the observations. Sequential probability ratio tests. Sequential design of experiments. Optimal stopping. Stochastic approximation. Mr. Simons

U.N.C. ST 222 NONPARAMETRIC INFERENCE 3(3-0) S
Prerequisites: U.N.C. ST 132, U.N.C. ST 135, U.N.C. ST 112

Estimation and testing when the functional form of the population distribution is unknown. Rank, sign, and permutation tests. Optimum non-parametric tests and estimators. Mr. Hoeffding

U.N.C. ST 232 GENERAL THEORY OF STATISTICAL DECISION 3(3-0) S
Prerequisites: U.N.C. ST 135, U.N.C. ST 112

Selected topics in the general theory of statistical decisions, based on the work of Abraham Wald. (Offered 1971-1972 and alternate years.) Mr. Hoeffding

U.N.C. ST 235 STOCHASTIC PROCESSES 3(3-0) S
Prerequisites: U.N.C. ST 112, U.N.C. ST 132

Advanced theoretic course including topics selected from: Foundations of stochastic processes, Renewal processes, Stationary processes, Markov processes, Martingales, Point processes. (Offered 1971 1972 and alternate years.)
Messrs. Leadbetter, Smith

U.N.C. ST 237 TIME SERIES ANALYSIS 3(3-0) S
Prerequisites: U.N.C. ST 112, U.N.C. ST 132

Analysis of time series data by means of particular models such as autogressive and moving average schemes. Spectral theory for stationary processes and associated methods for inference. Stationarity testing. (Offered 1972-1973 and alternate years.) Messrs. Leadbetter, Wegman, Cleveland

U.N.C. ST 251 COMBINATORIAL PROBLEMS OF THE DESIGN OF EXPERIMENTS 3(3-0) F
Prerequisite: U.N.C. ST 150

Finite fields and finite geometries. Construction of orthogonal Latin squares and balanced incomplete block designs. Confounding, construction and analysis of symmetrical and functional factorial designs. Mr. Bose

U.N.C. ST 252 INFORMATION THEORY 3(3-0) S
Prerequisite: U.N.C. ST 134

Transmission of information, entropy, message ensembles, discrete sources, transmission channels, channel encoding and decoding for discrete channels.
Mr. Rajput

U.N.C. ST 253 ERROR CORRECTING CODES 3(3-0) S
Prerequisite: U.N.C. ST 251 or consent of instructor

Linear codes and their error-correcting capabilities. Hamming codes. Reed-Muller codes. Cyclic codes. Bose Chaudhuri codes. Burst error correction. Majority logic decoding. Mr. Bose

U.N.C. ST 254 SPECIAL TOPICS IN DESIGN OF EXPERIMENTS I 3(3-0) F
Prerequisite: U.N.C. ST 150

Response surface designs. Conditions for rotatability. Construction and analysis of rotatable designs of the second and third order. Interblock analysis. General analysis of covariance. Missing plot techniques. Mr. Bose

U.N.C. ST 255 SPECIAL TOPICS IN THE DESIGN OF EXPERIMENTS II 3(3-0) S
Prerequisite: U.N.C. ST 251

Combinatorial properties and construction of balanced, group divisible and partially balanced designs. Impossibility proofs. Orthogonal Latin squares of non-prime power orders. Orthogonal arrays. Asymmetrical fractionally replicated designs. Mr. Bose

U.N.C. ST 260 MULTIVARIATE ANALYSIS 3(3-0) F
Prerequisites: U.N.C. ST 135 and matrices

Characterization and properties of a multivariate normal distribution. Related distributions. Tests and confidence intervals. Multivariate analysis of variance,

covariance and regression. Association between subsets of a multivariate normal set. Factor analysis. Mr. Johnson

U.N.C. ST 261 ADVANCED PARAMETRIC MULTIVARIATE ANALYSIS 3(3 0) S
Prerequisite: U.N.C. ST 260

Distribution problems involved in the normal theory analysis of general multivariate linear models including the growth curves. An introduction to zonal polynomials and orthogonal groups. Union-intersection principle and its role in multivariate analysis. (Offered 1970-1971 and alternate years.) Mr. Sen

U.N.C. ST 262 INTRODUCTORY NONPARAMETRIC MULTIVARIATE ANALYSIS 3(3-0) F
Prerequisites: U.N.C. ST 222, U.N.C. ST 260

The problem of symmetry in the multivariate case. Nonparametric tests for ANOVA and MANOVA in one-way layouts. Robust estimation of location and of contrasts in one-way MANOVA. Large sample properties of the tests and estimates. Mr. Sen

U.N.C. ST 263 ADVANCED NONPARAMETRIC MULTIVARIATE ANALYSIS 3(3 0) S
Prerequisite: U.N.C. ST 262

Robust nonparametric inference in various multifactor multiresponse experiments. The problem of multidimensional independence. Nonparametric inference in general linear models. (Offered 1971 72 and alternate years.) Mr. Sen

U.N.C. ST 300, 301 SEMINAR IN STATISTICAL LITERATURE 1(1-0) FS
Prerequisite: U.N.C. ST 135

Graduate Staff

U.N.C. ST 310, 311 SEMINAR IN THEORETICAL STATISTICS 3(3 0) FS
Prerequisite: U.N.C. ST 135

Graduate Staff

U.N.C. ST 321, 322 SPECIAL PROBLEMS 3(3-0) FS
Prerequisite: Consent of instructor

Graduate Staff

U.N.C. ST 331, 332 ADVANCED RESEARCH 3(3-0) FS
Prerequisite: Consent of instructor

Graduate Staff

Textiles

GRADUATE FACULTY

Professor DAVID W. CHANEY, *Dean*

Professors: JOHN F. BOGDAN, *Acting Head of the Department of Textile Technology,* KENNETH S. CAMPBELL, DAVID M. CATES, *Chairman of the Graduate Studies Committee for the Fiber and Polymer Science Program* RICHARD D. GILBERT, GEORGE GOLDFINGER, DAME S. HAMBY, *Director, Textiles Extension and Continuing Education,* SOLOMON P. HERSH, *Graduate Administrator in Textile Technology,* JOSEPH A. PORTER, JR., HENRY A. RUTHERFORD, *Head of the Department of Textile Chemistry,* ROBERT W. WORK,

Director of Research; Adjunct Professors: HERMAN R. MARK, ARNOLD M. SOOKNE; *Associate Professors:* JOHN A. CUCULO, A. H. M. EL-SHIEKH, PAUL D. EMERSON, *Head, Textile Machine Design Development*; T. WALLER GEORGE, THOMAS H. GUION, PETER R. LORD, RALPH MCGREGOR, THEODORE G. ROCHOW, WILLIAM C. STUCKEY, JR.; *Research Associate:* CARL E. BRYAN; *Assistant Professors:* PETER BROWN, WILLIAM D. COOPER, RAYMOND E. FORNES, BHUPENDER S. GUPTA, MICHAEL H. THEIL, WILLIAM K. WALSH; *Visiting Assistant Professor:* MANSOUR H. M. MOHAMED; *Adjunct Assistant Professor:* LOUIS A. GRAHAM.

The School of Textiles offers programs leading to the Master of Science degree in textile chemistry and in textile technology, the professional degree of Master of Textile Technology, and the Doctor of Philosophy in fiber and polymer science. (For a description of the Fiber and Polymer Science Program see page 153.)

The fundamental objectives of the graduate program in the School of Textiles are to provide the student with a sound education in a selected field and to develop his ability to initiate and conduct independent investigations which lead to the development of new knowledge. These objectives are accomplished through programs designed to give him a foundation in the basic sciences and to develop a broad and comprehensive understanding of a major field through study and research.

Students with Bachelor of Science or Bachelor of Arts degrees with majors in textiles, the physical sciences or engineering, combined with a strong background in mathematics, will normally qualify for the graduate degree programs.

The minimum requirement for a Master of Textile Technology degree is the satisfactory completion of 33 semester hours of advanced courses. There is no thesis or foreign language requirement. This program is designed to offer the student advanced professional training. Students pursuing this degree are encouraged to minor in economics with emphasis in the area of management.

The programs of study for the Master of Science degree include a minimum of 30 semester hours of advanced courses and a thesis based on research conducted by the student. There is no foreign language requirement. The plan of course work and the research activities for the Master of Science degree are designed to prepare the student for a career in research, development or other technical phases of the textile and allied industries. Students may minor in any one of a number of associated fields.

Programs of study may be arranged to develop a broad background in three general areas: advanced textile technology; production and marketing management of textiles; and textile chemistry. Those students interested in the first of these may emphasize areas such as fiber and yarn technology, fabric technology, knitting technology, and testing or quality control. Programs leading to the Master of Science degree in textile chemistry emphasize fiber and polymer chemistry. In the area of marketing and production management, the program emphasizes the applications of quantitative decision methods including operations research and computer techniques to the textile industry. Programs in this area normally terminate within the School of Textiles with either the Master of Textile Technology or Master of Science degree in textile technology, but may be structured to provide suitable backgrounds for students wishing to do further graduate work in the areas of economics, industrial management, industrial engineering or business administration.

Current research activities in the Department of Textile Chemistry emphasize fiber and polymer science including studies of the physical chemistry of dyeing,

color physics, polymer-solvent interactions, sorption and diffusion processes, mechanism of reactions with fibrous substrates, modification of fibrous polymers by radiation, water pollution abatement, thermal properties of polymers and polymer crystallization phenomena. In the Department of Textile Technology, research activities include fundamental studies of the formation of man-made fibers and their properties; yarn and fabric structure and properties; electrical, frictional and mechanical properties of fibers and yarns; noise abatement; and novel processes associated with current developments in materials and equipment.

The physical resources of the School of Textiles include all of the machines and equipment commonly used in the processing of natural and man-made fibers into yarns and woven, knitted and nonconventional fabrics including final dyeing and finishing. In addition, an unusually large variety of specialized research and testing equipment is available. These include such unique facilities as laboratories for color measurement and matching, for texturing yarns, for preparing man made fibers and for preparing fabrics by unconventional methods. Well equipped shop facilities and physics, electronics and instrumentation laboratories are also available in the school. A library containing specialized journals and books covering textiles, fibers, polymer science, and related subjects is conveniently housed within the school.

A number of assistantships and fellowships are available with stipends ranging from $2,700 to $3,600.

FOR ADVANCED UNDERGRADUATES

T 492 PROBLEMS IN SCIENCE AND TECHNOLOGY 1(0 2) S
Prerequisite: Junior standing

A series of lectures given by scientists and technologists from outside the University. The lectures to consist of the description of a scientific or technological problem, its analysis and its solution. The latter to be arrived at in cooperation with the class. The students write brief critical reviews of these lectures and discuss them in class. This course may be taken twice for a maximum of two credits. Messrs. Gilbert, George, Goldfinger

FOR GRADUATES AND ADVANCED UNDERGRADUATES

T 501 RESINOGRAPHY 3(1-4) FS
Prerequisites: TX 300 or TX 500 and TX 460 or TX 560 or TC 461 (CH 461)

Lectures, laboratory and discussion regarding structure and morphology of resins, fibers, elastomers and composites. Such materials will be studied by reflected light or electrons and by transmitted light or electrons. Other methods of diffraction and spectrometry will be discussed. Crystallographic and optical properties will be emphasized. Mr. Rochow

Textile Chemistry

(For a listing of graduate faculty and other information see textiles, page 307.)

FOR ADVANCED UNDERGRADUATES

TC 400 THE SCIENCE OF COLOR 3(3-0) FS
Prerequisite: Junior standing

The course is designed to acquaint the student with the physical concepts of color. The colorimetric and spectrophotometric methods of measuring color, the correlation of results with the subjective, physiological perception of color, and the principles of modern instrumental color matching are presented.

Mr. Goldfinger

TC 401 SOURCES AND CONTROL OF POLLUTION FROM THE TEXTILE INDUSTRY 3(3-0) S
Prerequisite: Consent of instructor

Contents of the course include the concept of water quality management, criteria of pollution, sources of pollution from fabric processing, plant surveys and in-plant remedial measures, principles of biological oxidation, current waste-treatment practices, and new developments and trends in pollution control. While the emphasis is on wastes from the textile industry, the student is introduced to the broader aspects of environmental pollution. Mr. Bryan

TC 403, 404 TEXTILE CHEMICAL TECHNOLOGY 3(3-0) FS
Prerequisites: (403) CH 223, TC 303

The chemistry involved in the wet processing of fibrous systems, especially dyeing, printing and finishing. The course emphasizes principles and includes a study of the various classes of dyes and their application to all important textile fibers and blends of fibers; preparatory and bleaching processes; roller printing and print formulations for important dye classes; nature and application of finishes for textiles. Mr. Campbell

TC 405, 406 TEXTILE CHEMICAL TECHNOLOGY LABORATORY 2(0-6) FS
Prequisites: TC 403, TC 404

To be taken concurrently with TC 403, 404. Mr. Livengood

TC 411 TEXTILE CHEMICAL ANALYSIS I 3(2-2) FS
Prerequisite: TC 301

The work includes a survey of textile chemicals, with emphasis on surfactants, warp sizes and fabric finishes of all types; the identification of fibers by chemical means, the qualitative and quantitative analyses of fiber blends by chemical means, the identification of finishes; the evaluation techniques for dyed and finished materials. (Not available for students majoring in textile chemistry.)

Mr. Livengood

TC 412 TEXTILE CHEMICAL ANALYSIS II 3(2-3) S
Prerequisite: CH 315

Application of certain techniques of analysis to fibers, textile chemicals and textile processes: ultraviolet, visible and infrared spectrophotometry; thin-layer and gas chromatography, viscometry; interfacial tension; calorimetric, gravimetric and mechanical thermal analyses. Emphasis on use of these techniques to solve problems of analysis involving such processes as sorption, solution, diffusion, crystallization, etc. Mr. Cates

TC 461 (CH 461) CHEMISTRY OF FIBERS 3(3-0) F
Prerequisite: CH 223

A lecture course emphasizing: the formation and properties of fiber-forming polymers; mechanism of addition and condensation polymerization; theories of

fiber structure, the relationship between the chemical structure and physical properties of natural and man-made fibers; the production of man-made fibers.
Messrs. Gilbert, Rutherford

TC 490 SPECIAL TOPICS IN TEXTILE CHEMISTRY 1-6 FS

Special topics relating to current developments in textile and polymer chemistry.
Staff

TC 491 SEMINAR IN TEXTILE CHEMISTRY 1(0-2) S
Prerequisite: TC 403

The course is designed to familiarize the student with the principal sources of textile chemical literature and to emphasize the importance of keeping abreast of developments in the field of textile chemistry. Particular attention is paid to the fundamentals of technical writing. Staff

FOR GRADUATES AND ADVANCED UNDERGRADUATES

TC 504 FIBER FORMATION THEORY AND PRACTICE 3(3 0) FS
Prerequisites: MA 301, PY 208 or consent of instructor

A practical and theoretical analysis of the chemical and physical principles underlying the conventional methods of converting bulk polymer to useful fiber; rheology; melt, dry and wet polymer extrusion; fiber drawing; heat setting; application of general theory to unit processes. Mr. Cuculo

TC 505 THEORY OF DYEING 3(3-0) FS
Prerequisite: CH 433

Mechanisms of dyeing. Application of thermodynamics to dyeing systems. Kinetics of diffusion in dyeing processes. Mr. McGregor

TC 561 ORGANIC CHEMISTRY OF HIGH POLYMERS 3(3-0) S
Prerequisites: TC 461 (CH 461), CH 331 or CH 431

Principles of step- and chain-growth polymerizations; co polymerization theory; homogeneous free radical polymerization; emulsion polymerization; Ziegler-Natta polymerization; ionic polymerization. Messrs. Gilbert, Theil

TC 562 (CH 562) PHYSICAL CHEMISTRY OF HIGH POLYMERS—BULK PROPERTIES 3(3-0) F
Prerequisites: CH 220 or CH 223; CH 331 or CH 431

Molecular weight description; states of aggregation and their interconversion; rubbery, glassy and crystalline states; rubber elasticity; molecular friction; diffusion and viscosity; dynamics of network response; retardation- and relaxation time spectra; thermodynamics of nucleation; kinetics of crystallization.
Messrs. Cates, Walsh

TC 569 (CHE 569) POLYMERS, SURFACTANTS AND COLLOIDAL MATERIALS 3(3-0) F
(See chemical engineering, page 91.)

FOR GRADUATES ONLY

TC 662 PHYSICAL CHEMISTRY OF HIGH POLYMERS—SOLUTION PROPERTIES 3(3-0) S
Prerequisites: CH 433, TC 562 (CH 562)

Sorption and diffusion; thermodynamics of polymer solutions; phase equilibria;

configurational and frictional properties; methods of determining molecular weight. Messrs. Cates, Walsh

TC 669 (CHE 669) DIFFUSION IN POLYMERS 2(2-0) S
(See chemical engineering, page 92.)

TC 671 (CHE 671) SPECIAL TOPICS IN POLYMER SCIENCE 1 3 F
(See chemical engineering, page 92.)

TC 691 (TX 691) SPECIAL TOPICS IN FIBER SCIENCE 1-3 S
(See textile technology, page 317.)

TC 698 SEMINAR FOR TEXTILE CHEMISTRY 1 FS

Discussion of scientific articles of interest to fiber and polymer science; review and discussion of student papers and research problems. Graduate Staff

TC 699 TEXTILE RESEARCH FOR TEXTILE CHEMISTRY Credits Arranged

Problems of specific interest to the textile industry will be assigned for study and investigation. The use of experimental methods will be emphasized. Attention will be given to the preparation of reports for publication. The master's thesis may be based upon the data obtained.

Textile Technology

(For a listing of graduate faculty and other information see textiles, page 307.)

FOR ADVANCED UNDERGRADUATES

TX 405 NON-CONVENTIONAL FABRIC STRUCTURES 3(3-0) F
Prerequisites: Senior standing and consent of instructor

An advanced study of systems for the direct conversion of fiber to fabrics. The total spectrum of possible fabric structure is surveyed and classified. Current marketable structures are analyzed with respect to production technologic, economic and property potential. Trends in direct conversion technology are discussed in detail to provide the student with a viable basis for participating in the evolution of the technology and its production. Messrs. George, Porter

TX 420 MODERN DEVELOPMENTS IN YARN MANUFACTURING SYSTEMS 3(3 0) S
Prerequisite: Senior standing

A course dealing with the newly emerging means of yarn production such as open-end, composite, self twist and twistless forms of spinning. The course will deal with the preprocesses and their effects on spinning; also with the after-processes to assess the effects of the new systems. Mr. Lord

TX 425 CONTINUOUS FILAMENT YARN SYSTEMS 3(2-2) FS Sum.
Prerequisites: TX 211, TX 220

A study of the structure of thermoplastic polymers in continuous filament form and their response to elevated temperatures, high velocity air flow and other methods of modification to produce bulked, textured and torque type yarns. A fundamental study of related properties such as stress relaxation, generation and control of electrostatic charges and responses to low order tensile forces.
Mr. Tucker

TX 426 LONG STAPLE AND TOW SYSTEMS 3(2-2) FS Sum.
Prerequisites: TX 211, TX 220

Principles of long staple yarn forming systems including the woolen, worsted, tow to top and compact carpet yarn systems. Emphasis is on the relationship of fiber structures and characteristics necessary to produce the desired properties and performance characteristics of such yarns as woolen and worsted blends with man-made fibers, bulked yarns and carpet yarns. Mr. Pardue

TX 431 SPECIAL TOPICS IN TESTING 3(2-2) F
Prerequisites: TX 330, senior or graduate standing

A topical presentation of special and advanced techniques for measuring selected physical and aesthetic properties of natural and man-made textile materials; application of physical laws to technique and instrumentation; interrelation of the material, method of test, instrumentation involved and the resulting physical measure. Mr. Stuckey

TX 441 ADVANCED WEFT KNITTING 3(2-2) F Sum.
Prerequisite: TX 340

A study of advanced weft knit mechanisms and fabrics. The development of new fabrics for specific end uses. Staff

TX 447 ADVANCED DESIGN OF KNITTING STRUCTURES 2(0 4) FS
Prerequisite: TX 340

Systematic study of circular hosiery mechanisms; hosiery types and constructions. Seamless hosiery production methods utilizing the newer synthetic yarns, toe closing methods, finishing processes and marketing are emphasized. Staff

TX 449 WARP KNITTING SYSTEMS 3(2-2) FS
Prerequisite: TX 340

A critical study of tricot, raschel, simplex and milanese machines. The emphasis will be on principles of production including quality and costing, and the limitations of each method will be discussed. The fabric properties will be related to end uses, and both recent developments and future trends will be discussed in terms of improvements in yarns and mechanisms. Fabric design and analysis will receive attention. Staff

TX 450 ADVANCED DESIGN AND WEAVING 3(2 2) FS
Prerequisite: TX 350

Advanced study of special weave formations and of new developments and research findings in the areas of warp preparation, design, weaving and fabric formation. Mr. Moser

TX 451 COMPLEX WOVEN STRUCTURES 3(2-2) S
Prerequisite: TX 450

The development of design specifications for complex fabrics as related to fabric geometry, functional and aesthetic properties and manufacturing limitations. Staff

TX 460 PHYSICAL PROPERTIES OF TEXTILE FIBERS 3(3-0) FS
Prerequisites: MA 212, PY 212

The course covers the structural, mechanical, thermal, optical, frictional and electrical properties of fibers and the effect of moisture on physical and mechanical properties. The influence of these properties on end use application and performance is discussed. Messrs. Fornes, Gupta, Hersh

TX 465 MECHANICS OF YARN FORMATION 3(2 2) F
Prerequisite: TX 320

Theoretical analysis of machine-fiber interactions for such functions as fiber blending, the carding actions, staple fiber attenuation and spun yarn formation. Laboratory experiments are designed to verify the analyses discussed in the lectures. Mr. El-Shiekh

TX 470 FABRIC STYLING AND DESIGN 2(2-0) FS
Prerequisites: Junior or senior standing and consent of instructor

A basic course in textile styling and design as influenced by aesthetic and end use considerations. The limitations and influence of current technology on design principles and aesthetic capabilities will be emphasized. Mrs. Massey

TX 480 TEXTILE COST CONTROL 3(3 0) FS Sum.
Prerequisites: EC 206, TX 320, TX 350

A study of cost methods applicable to textile costing with emphasis on decision-making. Interpretation of cost reports and their use in pricing and cost control.
Mr. Powell

TX 482 (EC 482) SALES MANAGEMENT FOR TEXTILES 3(3-0) S
Prerequisite: TX 380

Definition and analysis of the role of sales management in the textile industry. Areas of control and responsibility are reviewed. Analytical tools of sales management are studied and through case methods are brought into practical focus for the student. Mr. Cooper

TX 484 MANAGEMENT DECISION MAKING FOR THE TEXTILE FIRM 3(3-0) S
Prerequisite: TX 482 (EC 482)

A study of the economic and environment setting within which the textile firm makes decisions, and an application of various analytical tools, quantitative and qualitative in making these decisions. Strategies for implementing these decisions are explored. Mr. Cooper

TX 490 DEVELOPMENT PROJECT 2-3 FS Sum.
Prerequisites: Senior standing, consent of instructor

Introduction to research through experimental, theoretical and literature studies of textile and related problems. Staff

TX 491 SPECIAL TOPICS IN TEXTILES 1-3 FS
Prerequisite: Senior standing

Special topics relating to current developments in the textile industry. Staff

FOR GRADUATES AND ADVANCED UNDERGRADUATES

TX 500 ADVANCED MICROSCOPY 3(1-4) S
Prerequisite: TX 330 or consent of instructor

The art and science of light and electron microscopy and introduction to micro-radiography; theoretical and practical aspects of visibility, resolution and contrast. Laboratory practice in assembly, testing and using various microscopes and accessories in describing, identifying and micrographing crystalline, oriented, or amorphous materials, especially those which are of interest to the student. Laboratory work may include special projects for independent investigation.
Messrs. Gupta, Rochow

TX 530 TEXTILE QUALITY CONTROL 3(3-0) S
Prerequisite: TX 330 or consent of instructor

Quality control systems for textile operations with emphasis on sampling plans for attributes and variables and on interpretation of data as related to identifying sources of product variability. Mr. Stuckey

TX 550 FABRIC ANALYTICS 3(3 0) FS
Prerequisite: TX 350 or graduate standing

Development of a numerical system for characterizing designs. Permutations and combinations of weave elements. Correlation of fiber and yarn properties with those of the fabric. Engineering design of fabrics. Relationship between fabrics having geometrical similarity and the prediction of their physical properties. Mr. Bogdan

TX 560 STRUCTURAL AND PHYSICAL PROPERTIES OF FIBERS 3(3-0) F
Prerequisite: MA 301

Advanced study of the structure and physical properties (moisture, thermal, optical, frictional and electrical) of textile fibers. Theoretical relations and advanced techniques are presented and discussed. Mr. Gupta

TX 561 MECHANICAL AND RHEOLOGICAL PROPERTIES OF FIBROUS MATERIAL 3(2-2) S
Prerequisite: MA 301

In-depth study of the stress-strain, bending, torsional, dynamic and rheological behavior of natural and man-made fibers. Theoretical relations and advanced techniques are presented and discussed. Mr. Gupta

TX 585 (EC 585) MARKET RESEARCH IN TEXTILES 3(3-0) S
Prerequisites: MA 405, ST 421

A study and analysis of the quantitative methods employed in market research in the textile industry. The function of market research and its proper orientation to management and decision-making. Mr. Cooper

TX 590 SPECIAL PROJECTS IN TEXTILES 2-3 FS Sum.
Prerequisites: Senior standing or graduate standing, consent of instructor

Special studies in either the major or minor field of the advanced undergraduate or graduate student. These studies will include current problems of the industry, independent investigations, seminars and technical presentation, both oral and written. Graduate Staff

TX 591 SPECIAL TOPICS 1-4 FS
Prerequisite: Consent of instructor

An intensive treatment of selected topics involving textile technology. Graduate Staff

TX 598 TEXTILE TECHNOLOGY SEMINAR 2(2-0) S
Prerequisites: Senior standing, consent of instructor

Lecture and discussion of current topics relating to the textile industry. Graduate Staff

FOR GRADUATES ONLY

TX 601 STAPLE FIBER STRUCTURES I 3(2-2) S
Prerequisite: Graduate standing

Studies of advanced techniques in textile production; the technological aspects

of fiber properties in relation to processing; studies of research findings and application of these to processing equipment. Mr. Lord

TX 602 STAPLE FIBER STRUCTURES II 3(2-2) FS Sum.
Prerequisite: Graduate standing

Problems dealing with advanced textile production and the technological implications of fiber processing will be assigned for study and investigation. Attention will be given to the preparation of reports for oral and written presentation. Graduate Staff

TX 621 TEXTILE TESTING III 2(2-0) S
Prerequisite: TX 530 or equivalent

Design of textile laboratories, including conditioning equipment and instruments required for specific needs; performance of tests and analysis of data on industrial problems; specialized physical tests; interlaboratory tests and analysis; study of A.S.T.M. specifications and work on task groups for A.S.T.M. Society. Mr. Gupta

TX 631 SYNTHETIC FIBERS 2(1-2) FS Sum.
Prerequisite: TX 425 or TX 426 or equivalent

Lectures and projects on advanced problems associated with the properties and processing of man made continuous filament and staple fiber yarns. Mr. Hersh

TX 641, 642 ADVANCED KNITTING SYSTEMS AND MECHANISMS 3(3-0) FS
Prerequisite: TX 441 or equivalent

A critical study of inventions which have contributed to the development of the modern knitting industry; knitting needles and their adaption for specific uses; means for mounting them for individual and *en masse* operation; construction and functioning of cooperating elements including sliders, jacks, sinkers, dividers, pressing elements, narrowing and tensioning and draw-off motions, regulating mechanisms, timing and control chains and cams. Use will be made of patent literature which covers important developments in the hosiery industry. Mr. Brown

TX 643, 644 KNITTING TECHNOLOGY 3(1-4) FS
Prerequisites: Graduate standing, eight hours in knitting technology

Problems of specific interest to the knitting industry will be assigned for study and investigation. The use of experimental methods will be emphasized. Attention will be given to the preparation of reports for publication. Graduate Staff

TX 651, 652 FABRIC DEVELOPMENT AND CONSTRUCTION 3(1-4) FS
Prerequisite: Graduate standing

Application of advanced technology to the development and construction of woven fabrics. Mr. Porter

TX 663 (MAE 663) MECHANICS OF TWISTED STRUCTURES 3(3-0) F
Prerequisites: EM 301, TX 560

Study of the basic mechanics of fibrous assemblies. Geometry and mechanics of twisted structures (yarns, cords, braids . . .) and the translation of fiber properties into structural behavior. Mr. El-Shiekh

TX 664 (MAE 664) MECHANICS OF FABRIC STRUCTURES 3(3-0) S
Prerequisite: TX 663 (MAE 663)

Analysis of the geometry and behavior of woven, knitted and nonwoven fabrics under various stress conditions and end use applications. Mr. El-Shiekh

TX 680 SPECIAL PROJECTS IN TEXTILE MANAGEMENT 1-3 FS Sum.
Prerequisite: TX 585 (EC 585)

Special studies in textile management covering current problems of the industry, independent investigations, seminars and technical presentations, both oral and written. Mr. Cooper

TX 691 (TC 691) SPECIAL TOPICS IN FIBER SCIENCE 1-3 S
Prerequisite: Consent of instructor

The study of selected topics of particular interest in various advanced phases of fiber science. Graduate Staff

TX 698 SEMINAR 1(1-0) FS

Discussion of scientific articles of interest to the textile industry; review and discussion of student papers and research problems. Graduate Staff

TX 699 TEXTILE RESEARCH Credits Arranged

Problems of specific interest to the textile industry will be assigned for study and investigation. The use of experimental methods will be emphasized. Attention will be given to the preparation of reports for publication. The master's thesis may be based upon the data obtained. Graduate Staff

Toxicology

GRADUATE FACULTY

Professors: WILLIAM E. DONALDSON, DANIEL S. GROSCH, FRANK E. GUTHRIE, DON W. HAYNE, ERNEST HODGSON, ALEXANDER R. MAIN, ROBERT J. MONROE, DONALD E. MORELAND, JEROME J. PERRY, THOMAS J. SHEETS; *Adjunct Professors:* LAWRENCE FISHBEIN, JAMES R. FOUTS; *Associate Professor:* WALTER C. DAUTERMAN

The combined impact of population increase and urbanization has magnified the problem of environmental contamination in recent years. As technology attempts to keep pace with the increased demands of our complex civilization, additional toxicants will be introduced which may affect man and other animals. The need for increased scrutiny of toxic agents and an understanding of their mode of toxic action (especially in trace amounts) is evidenced by recent findings summarized in many reports by government and professional organizations.

A graduate minor in toxicology at the master's or doctor's level is available which provides the coordination necessary to offer the student an excellent background in toxicology. This is an interdepartmental program which draws faculty from the Departments of Biochemistry, Botany, Crop Science, Entomology, Genetics, Microbiology, Poultry Science, Statistics and Zoology. Students majoring in these and related subject matter departments may elect the toxicology minor.

Requirements for a minor at the M.S. level will be either TOX 510 or TOX 515 and for the Ph.D. degree both TOX 510 and 515. Additional courses from the supplementary list will be added at the discretion of the faculty member represent ing the minor (the same faculty member cannot represent both the major and

minor). The supplementary list includes: BCH 452, CH 428, GN 532 (ZO 532), BCH 551, BCH 557, BCH 652, ST 511, ST 512, ZO 614 and ENT 622.

The Toxicology Minor Program is administered by a Toxicology Advisory Committee whose chairmanship is on a rotational basis. Additional information about the program may be obtained by writing to one of the faculty mentioned above.

TOX 510 INTRODUCTION TO BIOCHEMICAL TOXICOLOGY 2(2-0) F
Prerequisites: Biochemistry, senior standing

Emphasis is placed on the molecular events that occur during the toxic action of xenobiotics, including penetration phenomena, and the enzymatic mechanisms involved in detoxication.

TOX 515 ENVIRONMENTAL TOXICOLOGY 2(2-0) S
Prerequisite: Two years of biology

The nature, distribution and significance of microchemical contamination will be discussed.

TOX 590 SPECIAL PROBLEMS IN TOXICOLOGY 1-3
Prerequisite: Graduate standing

TOX 690 TOXICOLOGY SEMINAR 1(1-0) S
Prerequisite: Graduate standing

Urban Design

GRADUATE FACULTY

Professors: ROBERT P. BURNS, JR., HENRY L. KAMPHOEFNER, RICHARD R. WILKINSON; *Associate Professors:* PETER BATCHELOR, HENRY SANOFF; *Assistant Professor:* ROGER H. CLARK

The Urban Design Program has been conceived as an area of specialization and concentration in support of growing professional activity in the planning and design of contemporary urban environments. Urban design is an interdisciplinary area involving two major professional and academic disciplines—architecture and city planning—and in recent years the technologically advanced nations in the world have begun to utilize urban design as a means of resolving problems related to the physical growth and development of cities. Acting on a manifest need for specialized skills in urban design, the Department of Architecture of the School of Design at North Carolina State University has combined its resources with those of the Department of City and Regional Planning at the University of North Carolina in Chapel Hill. Thus, the urban design program is a joint graduate program utilizing a diversified body of interdisciplinary expertise.

Students enrolled in the program through the Department of Architecture at the School of Design are candidates for the Master of Urban Design degree. The urban design program admits qualified candidates from both design and non-design backgrounds. A minimum of 48 semester hours is required to complete the degree requirements. Depending on the extent of preparation in design subjects and other specified prerequisites, a student may spend from four to six academic semesters

in course work. In addition, a period of internship is required in agencies or professional consultant's offices where urban design and planning problems are being handled. This period of internship can be waived upon evidence of equivalent prior experience, or it can be undertaken during the student's program of study as summer work experience.

The urban design program is strongly complemented by other graduate programs in the School of Design. Students in urban design have access to electives in many of the professional and non-professional courses offered in architecture, landscape architecture and product design. Moreover, the growing concept of interdisciplinary education has broadened the scope of an urban design education to the point where there are many minor fields of study. Therefore, students enrolled in the program are able to choose among a wide range of minor areas of specialization, some of which are as follows: urban physical systems, urban re development, urban technology, housing systems, production technology, natural systems and environmental policy planning.

The nature and complexity of the tasks which confront the urban designer make it paramount that the program be broadly based and diversified. Reasonable flexibility is provided to structure each student's program of study in accordance with expressed interests and demonstrated capabilities. Essentially, master's candidates are afforded concentrated education in depth so that they can prepare themselves for significant professional involvement in the urban design field as practitioners, teachers, researchers or in other more specialized areas.

A thorough mastery of this broad field requires that a graduate student attain a basic understanding of the structure of cities, the relevant technologies, the cultural and economic factors in design as well as procedural aspects of urban design and city planning. While a clear comprehension of these subjects is essential, the urban designer must also understand their interrelationships and must demonstrate competence in their application through physical design activity.

Design studio activity concentrations vary somewhat from year to year depending on faculty expertise and student interest. The Urban Design Program does identify with the societal needs of the community, state and region and sees the design studio as offering an appropriate opportunity for addressing society's most critical environmental conditions. In recent semesters studio options have included urban renewal and new towns design, programming, planning and design of urban physical systems, and many other related problems.

The program will require all students to undertake the normal two year master's program of a minimum of 48 credit hours of course work of which 50 percent will be in the major field, 25 percent in the minor field, and the remainder in independent research. Course work in the minor field will be selected to reinforce the student's individual abilities and long-range career goals.

Departmental resources, including both physical facilities and faculty, are of exceptional quality. Members of the graduate faculty have been widely recognized for the excellence of their educational and professional accomplishments. A number of the faculty are active in independent consultation and private architectural and urban design practice and have received numerous awards for design. Resources directly available to the master's program in urban design include graduate faculty members from the Departments of Architecture, Landscape Architecture, Product Design and City and Regional Planning, as well as from related fields such as social sciences and engineering. The possibilities for interdisciplinary studies with these faculty members is a major strength of the program.

The recent establishment of the Center of Environmental Design as the official research and service agency of the School of Design provides a highly visible and

flexible mechanism to facilitate the School's mission in this vitally important area of faculty and student activity. The Center will make it possible for the School of Design to pursue a far more active role in funded research and development, community service and continuing education.

The Urban Design Program has access to all the facilities in the School of Design, which is housed in Brooks Hall. Design studios, lecture and seminar rooms, extensive shop facilities, well-equipped visual and photographic laboratories, exhibition and lounge spaces and a large design research laboratory are available in the School of Design for graduate studies. In addition, the School of Design Library has a large and fast-growing collection of books and slides and constitutes a major resource for the graduate program in urban design.

Research assistantships and fellowships are available for qualified applicants. A bulletin and pertinent information describing in detail opportunities for graduate study and research in the urban design program are available upon request from the director of the program.

FOR GRADUATES AND ADVANCED UNDERGRADUATES

UD 501 INTRODUCTORY PROBLEMS IN URBAN DESIGN 3(0 6) F
Prerequisite: Graduate standing

Introduction to descriptive analysis of physical and socio-economic phenomena of urban environments, and application of research methods in the definition and resolution of urban design problems.

UD 502 URBAN DESIGN WORKSHOP I 3(0-6) S
Prerequisite: UD 501

A complete synthesis of design factors influencing an environmental system or an urban complex.

UD 520 THEORY AND PRINCIPLES OF URBAN DESIGN 3(3-0) S
Prerequisite: Graduate standing

An examination of the nature of the design process in urban environments with special emphasis on contemporary theory and practice.

UD 590 SPECIAL TOPICS IN URBAN DESIGN I 1-6 FS
Prerequisite: Fourth year standing

This course provides a flexible means for investigation into areas of special interest related to urban design. It is intended primarily to encourage independent study and research.

UD 595 ENVIRONMENTAL PERCEPTION 3(3-0) S
Prerequisite: Graduate standing

The course is designed to acquaint the student with the theories and research on the perception of urban environments. Emphasis is placed on the visual attributes as well as user perceptions of the environment with a focus on the structuring of research to explore these dimensions.

FOR GRADUATES ONLY

UD 601 URBAN DESIGN WORKSHOP II 6(0-12) F
Prerequisite: UD 502

Analysis of complex environmental problems ranging in scale from area redevelopment to new towns design.

UD 602 ADVANCED PROBLEMS IN URBAN DESIGN 6(0 12) S
Prerequisite: UD 601

Investigation of current urban design problems with special emphasis on individual research and investigation.

UD 610 THEORY OF URBAN FORM 3(3-0) S

Prerequisite: Graduate standing

Survey of interdisciplinary theory of urban growth and evolution with about one-half of the class periods devoted to historical development of theory, and the other half devoted to contemporary quantitative models of urban form.

UD 690 SPECIAL TOPICS IN URBAN DESIGN II 1 6 FS
Prerequisite: Interdisciplinary core and integrative core in urban design

A course designed to allow for independent study and research in areas of special interest for graduate students in urban design only.

Water Resources

(An interdepartmental, intercampus graduate program)

WATER RESOURCES COMMITTEE RALEIGH CAMPUS

DR. EDWARD H. WISER (Biological and Agricultural Engineering), *Chairman*
DR. WILLIAM J. BLOCK (Politics), DR. ERIC ELLWOOD (Forest Resources), DR. WILLIAM W. HASSLER (Zoology), DR. D. W. HAYNE (Statistics), PROFESSOR DAVID H. HOWELLS (Water Resources Research Institute), *Secretary*, DR. VICTOR A. JONES (Food Science), DR. J. F. LUTZ (Soil Science), DR. T. E. MAKI (Forestry), DR. DAVID B. MARSLAND (Chemical Engineering), DR. H. H. NEUNZIG (Entomology), PROFESSOR HENRY A. RUTHERFORD (Textile Chemistry), DR. HAROLD E. SCHLICHTING (Botany), DR. JAMES A. SEAGRAVES (Economics), DR. T. JACK SHEETS (Entomology), PROFESSOR CHARLES SMALLWOOD (Civil Engineering), DR. CHARLES W. WELBY (Geosciences), PROFESSOR RICHARD R. WILKINSON (Landscape Architecture)

Water is a vitally important and unique resource. It is an essential ingredient of life, and civilizations have withered in its absence. The total supply is adequate; yet, variability in supply and demand create problems of scarcity and excess. Water is a renewable resource, but the intensity and multiplicity of use bring conflict and deterioration in quality. The increasing thirst of a rapidly developing land can only be met by intelligent management which takes into consideration all aspects of man's changing needs.

Water resources management is a major issue throughout the country and national policy supports strong water resources programs at all levels of government. These are multidisciplinary undertakings and require understanding of the many complex effects of conservation and development on all of society's interests. They require well-trained specialists in engineering and the physical, biological and social sciences who also possess a sound grasp of overall objectives and a full appreciation of the respective roles of the participating disciplines.

Water resources is generally considered to be an area of specialization and not a discipline. Graduate education should provide an opportunity for broad training

in water related subjects along with intense study in the major disciplines. Students with an interest in water resources should be encouraged to reach beyond their own departments for courses to extend their range of understanding and to participate in water resources courses and seminars designed to develop interdisciplinary communication and a basis for future working relationships.

A large number of courses related to water resources conservation, development and management are currently offered on the North Carolina State and University at Chapel Hill campuses. There is a highly qualified faculty representative of the multiplicity of disciplines involved. In order to capitalize on the combined training resources of both campuses and to offer them in an organized way to graduate students seeking interdisciplinary training in this field, an intercampus graduate minor in water resources has been established.

The program offers a strong graduate minor in water resources, with the major in any of the basic disciplines contributing to water resources planning, conservation, development and management. The graduate courses currently offered on both campuses have been reviewed, and courses dealing with water resources have been separated into the following general areas:

Water law and institutions
Planning of water resources and related systems
Municipal and industrial water management
Agricultural and forest water management
Aquatic biology and ecology
Hydrology and hydrogeology

Graduate students majoring in any discipline closely allied with one of the designated water resource areas will be qualified for admission to the program. They will be expected to select their water resources minor courses from one or more areas outside their major. The cohesive elements in the graduate program will be two interdisciplinary core courses including a water resources seminar and a course in water resources planning or water resources economics. The core courses to be presented on the Raleigh campus are described as follows:

EC 515 WATER RESOURCES ECONOMICS 3(3-0)

The application of economic principles in the allocation of water resources. Attention is given especially to the basic issues of how to effect maximum economic efficiency in the use of a resource that is no longer a free good, under the consider ation of the goals of the public and private sectors of the enterprise economy. Both economical and political consequences of decision making are studied.

Graduate Staff

CE 591 CIVIL ENGINEERING SEMINAR (WATER RESOURCES SEMINAR) 1(1-0) F

As offered for the water resources minor, this seminar provides an overview of water resources conservation, planning, development and management. Topics presented by visiting lecturers and graduate faculty. Mr. Howells

The minimal course requirements for a graduate minor in water resources are:

Master's Degree—The two core courses in water resources plus two courses in water resource areas outside the major discipline approved by the student's advisory committee;

Ph.D. Degree The two core courses in water resources plus five other courses in water resource areas outside the major discipline approved by the student's

advisory committee. The complete listing of courses available under this program is as follows:

WATER RESOURCES CORE COURSES

*Campus	Course	Title
R	CE 591	CIVIL ENGINEERING SEMINAR
	or	(WATER RESOURCES SEMINAR)
CH	ENVR 183	WATER RESOURCES SEMINAR
R	EC 515	WATER RESOURCES ECONOMICS
	or	
CH	ENVR 284 (PLAN 234)	PLANNING OF WATER RESOURCE SYSTEMS

LAW AND INSTITUTIONS OF WATER RESOURCES

R	PS 502 (ED 502)**	PUBLIC ADMINISTRATION
R	PS 511	THE BUDGETARY PROCESS
R	PS 516	PUBLIC POLICY ANALYSIS
R	PS 542	GOVERNMENTAL PLANNING
CH	PLAN 230	PLANNING LAW
CH	PLAN 233**	NATURAL RESOURCE LAW AND POLICY
CH	POLI 101***	PUBLIC ADMINISTRATION
CH	POLI 238	INTERGOVERNMENTAL RELATIONS
CH	POLI 181	NATIONAL POLICY AND ADMINISTRATION

PLANNING OF WATER RESOURCES AND RELATED SYSTEMS

R	CE 575**	CIVIL ENGINEERING SYSTEMS
CH	ECON 199	ECONOMICS OF ENVIRONMENTAL QUALITY
CH	ENVR 217**	SYSTEMS ANALYSIS IN ENVIRONMENTAL PLANNING
CH	ENVR 277	ENGINEERING PROJECT DESIGN
CH	GEOG 156	GEOGRAPHY OF NATURAL RESOURCES

Campus	*Course*	*Title*
CH	PLAN 232 (ENVR 282)**	PUBLIC INVESTMENT THEORY AND TECHNIQUES
CH	PLAN 241	ENVIRONMENTAL PLANNING

MUNICIPAL AND INDUSTRIAL WATER MANAGEMENT

R	BAE 578 (CE 578)	AGRICULTURAL WASTE MANAGEMENT
R	CE 383	WATER RESOURCES ENGINEERING I
R	CE 571	THEORY OF WATER AND WASTE TREATMENT
R	CE 572	UNIT OPERATIONS AND PROCESSES IN WASTES ENGINEERING
R	CE 573	ANALYSIS OF WATER AND WASTES
R	CE 574/ NE 592	RADIOACTIVE WASTE DISPOSAL/SPECIAL TOPICS IN NUCLEAR ENGINEERING II
R	CE 671	ADVANCED WATER SUPPLY AND WASTE WATER DISPOSAL
R	CE 672	ADVANCED WATER AND WASTES TREATMENT
R	CE 673	INDUSTRIAL WATER SUPPLY AND WASTE DISPOSAL
R	CE 674	STREAM SANITATION
R	TC 401	SOURCES AND CONTROL OF POLLUTION FROM THE TEXTILE INDUSTRY
R	FS 690	SEMINAR IN FOOD SCIENCE
CH	ENVR 123**	ANALYTICAL METHODS IN ENVIRONMENTAL CHEMISTRY AND BIOLOGY I
CH	ENVR 171**	PRINCIPLES OF WATER QUALITY MANAGEMENT
CH	ENVR 174	WATER AND WASTE TREATMENT PROCESSES
CH	ENVR 223	ANALYTICAL METHODS IN ENVIRONMENTAL CHEMISTRY AND BIOLOGY II
CH	ENVR 231**	ENVIRONMENTAL MICROBIOLOGY
CH	ENVR 132**	LIMNOLOGY AND WATER POLLUTION
CH	ENVR 272**	WATER SUPPLY AND WASTEWATER DISPOSAL SYSTEMS

*Campus	Course	Title
CH	ENVR 273	WATER AND WASTEWATER TREATMENT PLANT DESIGN
CH	ENVR 275	INDUSTRIAL WATER QUALITY MANAGEMENT

AGRICULTURAL AND FOREST WATER MANAGEMENT

R	BAE 321	IRRIGATION, TERRACING AND EROSION CONTROL
R	BAE 472	AGRICULTURAL WATER MANAGEMENT
R	FOR 472	RENEWABLE RESOURCE MANAGEMENT
R	FOR 501	FOREST INFLUENCE AND WATERSHED MANAGEMENT
R	FOR 692	ADVANCED FOREST MANAGEMENT PROBLEMS
R	RRA 440	RECREATION RESOURCES INVENTORY AND PLANNING
R	SSC 461**	SOIL AND WATER CONSERVATION

AQUATIC BIOLOGY AND ECOLOGY

R	BO 560 (ZO 560)**	PRINCIPLES OF ECOLOGY
R	BO 574 (MB 574)	PHYCOLOGY
R	CE 570 (MB 570)	SANITARY MICROBIOLOGY
R	MAS 529	BIOLOGICAL OCEANOGRAPHY
R	MAS 693	COASTAL ECOLOGICAL SYSTEMS
R	ZO 420	FISHERY SCIENCE
R	ZO 519**	LIMNOLOGY
R	ZO 619	ADVANCED LIMNOLOGY
R	ZO 621	FISHERY SCIENCE
CH	BOTN 114	ALGAE
CH	BOTN 141	ECOLOGY
CH	BOTN 216	MARINE ALGAE

*Campus	Course	Title
CH	ENVR 225 (MSCS 105)	CHEMICAL OCEANOGRAPHY
CH	ENVR 233	MICROBIAL ECOLOGY
CH	ENVR 235	ECOLOGY OF PHYTOPLANKTON
CH	ZOOL 108	ECOLOGY
CH	ZOOL 109**	INTRODUCTION TO HYDROBIOLOGY
CH	ZOOL 126 (MSCS 101)**	OCEANOGRAPHY
CH	ZOOL 140S (MSCS 104S)**	BIOLOGICAL OCEANOGRAPHY
CH	ZOOL 141S	SPECIAL PROBLEMS IN MARINE BIOLOGY
CH	ZOOL 146	MARINE ECOLOGY
CH	ZOOL 213	ADVANCED MARINE ECOLOGY
CH	ZOOL 226	ECOLOGICAL AND GENERAL SYSTEMS THEORY

HYDROLOGY AND HYDROGEOLOGY

R	BAE 671 (SSC 671)	THEORY OF DRAINAGE: SATURATED FLOW
R	BAE 674 (SSC 674)	THEORY OF DRAINAGE: UNSATURATED FLOW
R	CE 484**	WATER RESOURCES ENGINEERING II
R	CE 580	FLOW IN OPEN CHANNELS
R	CE 581	INTRODUCTION TO OCEANOGRAPHIC ENGINEERING
R	CE 643	HYDRAULICS OF GROUND WATER
R	CE 644	GROUND WATER ENGINEERING
R	GY 486	WEATHER AND CLIMATE
R	GY 563	APPLIED SEDIMENTOLOGY
R	GY 565**	HYDROGEOLOGY
R	GY 567	GEOCHEMISTRY
R	GY 581	GEOMORPHOLOGY
R	OY 487 (MAS 487, CE 487)	PHYSICAL OCEANOGRAPHY

*Campus	Course	Title
R	GY 584 (MAS 584)	MARINE GEOLOGY
R	MY 411	INTRODUCTORY METEOROLOGY
R	MY 555	METEOROLOGY OF THE BIOSPHERE
R	SSC 511	SOIL PHYSICS
CH	ENVR 281	TOPICS IN ADVANCED HYDROLOGY
CH	GEOG 110	METEOROLOGY
CH	GEOG 112	MICROMETEOROLOGY
CH	GEOG 115	CLIMATOLOGY
CH	GEOL 104	GEOMORPHOLOGY
CH	GEOL 142	PRINCIPLES OF GEOCHEMISTRY
CH	GEOL 173 (MSCS 103)	GEOLOGICAL OCEANOGRAPHY
CH	GEOL 242	PHYSICAL GEOCHEMISTRY
CH	GEOL 247	SEDIMENTATION
CH	GEOL 250	ADVANCED SEDIMENTATION
CH	MSCS 102	PHYSICAL OCEANOGRAPHY
CH	MSCS 206	SEMINAR ON OCEANOGRAPHY

*Courses bearing the prefix "R" are taught at Raleigh and those bearing "CH" at Chapel Hill. Unlisted courses can be substituted for listed courses with the approval of the student's advisory committee.
**Courses from which requirements for master's degree minor will normally be met. Substitutions can be made with approval of the student's advisory committee.
***Prerequisites can be waived for graduate students with water resources minor.

Request for information regarding the water resources graduate programs should be directed to the Chairman of the Water Resources Committee, the departments represented on the Water Resources Committee or the Water Resources Research Institute, 124 Riddick Building, North Carolina State University, Raleigh 27607.

Wood and Paper Science

GRADUATE FACULTY

Professor IRVING S. GOLDSTEIN, *Head*
Professors: ALDOS C. BAREFOOT, JR., ROY M. CARTER, ELLIS B. COWLING, ERIC L. ELLWOOD, *Dean, School of Forest Resources*; C. ARTHUR HART, ROBERT G. HITCHINGS, RICHARD J. THOMAS; *Professor Emeritus:* ALFRED J. STAMM; *Adjunct Professor:* STANLEY K. SUDDARTH; *Associate Professors:* JOSEF S. GRATZL, CHESTER G. LANDES, MICHAEL P. LEVI, WILLIAM T. MCKEAN, JR.,

RONALD G. PEARSON; *Adjunct Associate Professors:* PEDER J. KLEPPE, ROBERT K. STEVENS; *Assistant Professors:* HOU MIN CHANG, D. LESTER HOLLEY

Graduate study programs leading to the Master of Science and the Doctor of Philosophy degrees are offered for students in a wide variety of areas in the field of wood and paper science. The Master of Wood and Paper Science is available for students who do not wish to emphasize research in their graduate study program.

Graduate students can concentrate their field of study in wood science and technology, in pulp and paper science and technology, or in wood chemistry. A feature of the program is its flexibility and the opportunity to take interdisciplinary work or concentrate study in any of a number of disciplines that can be applied to the field of wood and paper science. The department works with each student to formulate a program suited to his needs.

Because the field of wood and paper science is a derived science, considerable emphasis is placed upon developing a strong minor in the graduate program in any one or more of the supporting disciplines such as organic chemistry, polymer chemistry, chemical engineering, mathematics, statistics, biology, engineering mechanics, mechanical engineering, physics, economics or business administration.

Areas of study and research in pulp and paper science and technology cover wood and fiber chemistry, lignin and carbohydrate chemistry, pulping chemistry, pollution abatement processes, fiber and paper properties, and paper coatings and additives. In wood science and technology, study and research areas include wood physics (especially wood liquid relations), wood chemistry, wood biology, wood mechanics and engineering, manufacturing processes, operations research applications, wood industry economics and marketing.

Many of these areas of research are carried under contracts, grants or cooperative agreements with government agencies and industry through which graduate student assistantships are financed. The department also participates in interdisciplinary programs with other departments to provide research and training programs in such fields as air and water and industrial waste control and abatement. These programs provide excellent career opportunities for those students interested in enhancement of the environment.

The Department of Wood and Paper Science is housed in the School of Forest Resources Biltmore Hall complex which includes the Brandon P. Hodges Wood Products Laboratory and the Reuben B. Robertson Wing which accommodates the research and teaching facilities for pulp and paper science and technology. These modern facilities are completely equipped to conduct education and research in all forms of wood and fiber processing. The complex includes specialized laboratories for study of wood physics, wood anatomy, wood processing, wood engineering, wood chemistry, pulping, papermaking, paper testing and paper coating. Equipment available includes optical and electron microscopes, a range of spectrophotometers, an ultracentrifuge, membrane osmometers, electron spin resonance and nuclear magnetic resonance apparatus.

Prerequisites for graduate study in the department are an undergraduate degree in wood science, in pulp and paper science or in a related science or in disciplines such as any of a number of branches of science or engineering.

FOR ADVANCED UNDERGRADUATES

WPS 403 PAPER PROCESS ANALYSIS 3(0-6) S

Manufacture of several types of papers with particular attention to stock preparation, sizing, filling and coloring. The finished products are tested physically and

chemically and evaluated from the standpoint of quality and in comparison with the commercial products they are intended to duplicate. Mr. Hitchings

WPS 411, 412 PULP AND PAPER UNIT PROCESSES 3(3-0) FS

Principles of operation, construction and design of process equipment employed in the pulp and paper industry. Mr. Rogers

WPS 413 PAPER PROPERTIES AND ADDITIVES 4(1-9) F

Physical, chemical and microscopical examination of experimental and commercial papers and evaluation of the results in terms of the utility of the product tested; evaluation and identification of dyestuffs and the development of color formulas. Mr. Landes

WPS 423 (FOR 423) LOGGING AND MILLING 3(2-3) F

Analysis of timber harvesting and transportation systems, equipment selection and costs; safety and supervision; manufacturing methods; log and lumber grades; analysis of investment alternatives. Mr. Mullin

WPS 434 WOOD OPERATIONS I 3(2-3) F
Prerequisites: WPS 301, WPS 302

Organization of manufacturing plants producing wood products, including company organization, plant layout, production planning and control. Analysis of typical manufacturing operations in terms of processes, equipment, size and product specification. The organization and operation of wood products markets. Mr. Carter

WPS 435 (FOR 435) SYSTEMS ANALYSIS IN FOREST PRODUCTS 3(3-0) S
Prerequisite: Senior standing

The application of the techniques of operations analysis to management decision-making in the wood products field. Allocation of production resources, inventory of raw materials, scheduling of production activities and general problems of quantitative decision-making. Mr. Hafley

WPS 441 INTRODUCTION TO WOOD MECHANICS 2(2-0) F
Prerequisite: MA 212, PY 221 or PY 211

Strength and related properties of commercial woods; standard A.S.T.M. strength tests; toughness; timber fastening; design of columns; simple, laminated and box beams; trusses and arches. Mr. Pearson

WPS 442 WOOD MECHANICS AND DESIGN 3(2-3) S
Prerequisite: EM 211 or WPS 441

The course will provide an understanding of wood as an engineering material. Topics include—generalized Hooke's law for orthotropic bodies and the effect of orientation of applied forces relative to the axes of symmetry; mechanical properties of wood as affected by its cellular structure; influence of defects, moisture, temperature and duration of load; visual and mechanical grading; derivation of working stresses; glued laminated construction; structural plywood, design of wooden members. Mr. Pearson

WPS 461 PAPER CONVERTING 1(1-0) S

A survey of the principal processes by which paper and paper board are fabricated into the utilitarian products of everyday use. Mr. Landes

WPS 463 PLANT INSPECTIONS 1(0-3) S

One-week inspection trips covering representative manufacturers of pulp and paper and paper-making equipment. Staff

WPS 471 PULPING PROCESS ANALYSIS 4(1-9) F

Preparation and evaluation of the several types of wood pulp. The influence of the various pulping and bleaching variables on pulp quality are studied experimentally and these data evaluated critically. Mr. Hitchings

WPS 481 PULPING PROCESSES AND PRODUCTS 2(2-0) S
Prerequisites: WPS 202, CH 103

Technology and economics of pulp products and by-products, including: paper and paperboard, containers and boxes, structural boards, molded and laminated products, cellulose fibers and films, cellulose derivatives and silvichemicals.
Mr. Landes

WPS 482 PULP AND PAPER MILL MANAGEMENT 2(2-0) S

A survey of decision making processes in pulp and paper mill management. A study of quantitative decision-making processes appropriate to various mill departments and functions. Staff

WPS 491 (FOR 491) SENIOR PROBLEMS IN FOREST RESOURCES Credits Arranged
Prerequisite: Consent of department

Problems selected with faculty approval in the areas of management or technology. Staff

WPS 492 (FOR 492) SENIOR PROBLEMS IN FOREST RESOURCES Credits Arranged
Prerequisite: Consent of department

Problems selected with faculty approval in the areas of management or technology. Staff

FOR GRADUATES AND ADVANCED UNDERGRADUATES

WPS 513 TROPICAL WOODS 2(1-3) F
Prerequisites: WPS 203, WPS 301

Structure, identification, properties, characteristics and use of tropical woods, especially those used in plywood and furniture. Mr. Barefoot

WPS 521, 522 CHEMISTRY OF WOOD AND WOOD PRODUCTS 3(2-3) FS
Prerequisites: CH 315, CH 331, WPS 202, PY 212

Fundamental chemistry and physics of wood and wood components; pulping principles; electrical and thermal properties. Mr. Gratzl

WPS 525 POLLUTION ABATEMENT IN FOREST PRODUCTS INDUSTRIES 3(3-0) S
Prerequisite: Graduate or advanced undergraduate standing in science or engineering curricula

The course will deal with pollution sources, inplant control and treatment of water and air pollution in forest products. In the main, the course will concentrate upon inplant pollution control in the pulp and paper industry. Staff

WPS 533 ADVANCED WOOD STRUCTURE AND IDENTIFICATION 2(1-3) F
Prerequisite: WPS 202

Advanced microscopic identification of the commercial woods of the United States and some tropical woods; microscopic anatomical features and laboratory techniques. Mr. Barefoot

WPS 591 (FOR 591) WOOD AND PAPER SCIENCE PROBLEMS Credits Arranged
Prerequisite: Senior or graduate standing

Assigned or selected problems in the field of silviculture, logging, lumber manufacturing, pulp technology or forest management. Staff

WPS 599 (FOR 599) METHODS OF RESEARCH IN WOOD AND PAPER SCIENCE
Credits Arranged

Prerequisite: Senior or graduate standing

Research procedures, problem outlines, presentation of results; consideration of selected studies by forest research organizations; sample plot techniques. Staff

FOR GRADUATES ONLY

WPS 604 TIMBER PHYSICS 3(3-0) FS
Prerequisite: WPS 441

Density, specific gravity and moisture content variation affecting physical properties; physics of drying at high and low temperatures; thermal, sound, light and electrical properties of wood. Mr. Hart

WPS 605 DESIGN AND CONTROL OF WOOD PROCESSES 3(3-0) FS
Prerequisite: WPS 604

Design and operational control of equipment for processing wood. Staff

WPS 606 WOOD PROCESS ANALYSIS 3(3-0) F
Prerequisite: WPS 604

Analysis of wood process through the solution of comprehensive problems involving the physics of temperature and moisture relations. Staff

WPS 607 ADVANCED QUALITY CONTROL 3(3-0) S
Prerequisites: WPS 606, ST 515

Advanced statistical quality control as applied to wood processing.
Mr. Barefoot

WPS 691 (FOR 691) GRADUATE SEMINAR 1(1 0) FS
(See forestry, page 164.)

WPS 693 ADVANCED WOOD TECHNOLOGY PROBLEMS Credits Arranged
Prerequisite: Graduate standing

Selected problems in the field of wood technology. Graduate Staff

WPS 699 (FOR 699) PROBLEMS AND RESEARCH Credits Arranged
(See forestry, page 164.)

Zoology

GRADUATE FACULTY

Professor DAVID E. DAVIS, *Head*
Professors: FREDERICK S. BARKALOW, JR., DANIEL S. GROSCH, REINARD HARKEMA, WILLIAM W. HASSLER, DON W. HAYNE, JOHN E. HOBBIE, BERNARD S. MARTOF, LAWRENCE E. METTLER, GROVER C. MILLER, THOMAS L. QUAY; *Professor Emeritus:* BARTHOLOMEW B. BRANDT; *Adjunct Professors:* DOUGLAS H. K. LEE, THEODORE R. RICE, PETER N. WITT; *Associate Professors:* BILLY J. COPELAND, CHARLES F. LYTLE, JOHN F. ROBERTS, DONALD E. SMITH; *Adjunct Associate Professors:* JOHN G. VANDENBERGH, RICHARD B. WILLIAMS, DOUGLAS B. WOLFE; *Assistant Professors:* GEORGE T. BARTHALMUS, PHYLLIS C. BRADBURY, W. F. STANDAERT; *Adjunct Assistant Professor:* FORD A. CROSS

The Department of Zoology offers to qualified students the opportunity to earn the Master of Science and the Doctor of Philosophy degrees. Students may specialize in many areas: behavior, general ecology, population dynamics, limnology, marine biology, fisheries biology, wildlife biology, taxonomy and ecological life histories of parasites, comparative morphology and systematics of vertebrates, cellular and comparative physiology, and endocrinology. For certain specialities, a degree without a thesis is awarded.

The department is located in Gardner Hall where facilities for a wide variety of research activities are available. Excellent opportunity for many types of ecological studies is provided in the extensive natural areas of state parks; some are only six miles from campus. Several off-campus laboratories are available to students and staff.

By mutual agreement, a student may choose to do research with any member of the graduate staff. A student will make up a plan of study after discussing his interests and objectives with his major professor and advisory committee. Those courses will be selected that best prepare him for his particular interests. Advanced courses in other departments provide a variety of subjects for minor fields of study: botany, entomology, genetics, statistics, biomathematics, biochemistry, psychology and other related sciences. The student is given the opportunity to develop a high order of independent thought, broad knowledge, technical skills and thorough training in investigative techniques. Strong emphasis is placed on active participation in seminars, practice in the methods of original research and preparation of manuscripts for publication in scientific journals.

A prospective student must submit Graduate Record Examination scores for the verbal, quantitative and advanced tests with the application for admission.

SPECIAL FACILITIES FOR MARINE RESEARCH

The Pamlico Marine Laboratory near Aurora, North Carolina, is located on the Pamlico River Estuary not far from Pamlico Sound. The research concerns both basic marine ecology and the effects of man's activities on the natural estuarine environment, particularly industrial and domestic pollution.

The Mid Atlantic Coastal Fisheries Research Center at Beaufort, North Carolina, is supported by the National Marine Fisheries Service and by the Atomic Energy Commission. After consultation with his adviser a student may arrange to conduct his research at the excellent facilities at Beaufort.

The Hatteras Marine Laboratory is located at the southern end of Hatteras Island, North Carolina, where a variety of interesting biological habitats occur. Cape Hatteras is the closest point to the Gulf Stream north of Daytona Beach, Florida. Both northern and southern faunas are found in adjacent waters.

FOR ADVANCED UNDERGRADUATES

ZO 401 (ENT 401) BIBLIOGRAPHIC RESEARCH IN BIOLOGY 1(1-0) F
(See entomology, page 151.)

ZO 414 (BO 414) CELL BIOLOGY 4(3-3) F
(See botany, page 83.)

ZO 420 FISHERY SCIENCE 3(2-3) F
Prerequisites: ZO 201, ZO 360

The science of fishery biology: life history and biology of important game and commercial fishes, fishing methods, age and growth analysis, survey of fishery resources, tagging studies, population estimations and pollution studies.

ZO 421 VERTEBRATE PHYSIOLOGY 4(3 3) FS
Prerequisites: Organic chemistry, physics, ZO 201

Physiology of vertebrates with emphasis on mammals. A comprehensive study of the mechanisms that operate to sustain life.

ZO 441 ICHTHYOLOGY 3(2-3) S
Prerequisite: ZO 223 or ZO 351

The classification and ecology of selected groups of fishes. Lectures, laboratories and field trips dealing with systematics, life histories, inter relationships and distribution.

FOR GRADUATES AND ADVANCED UNDERGRADUATES

ZO 501 ORNITHOLOGY 3(2 3) S
Prerequisites: ZO 223 or ZO 351, ZO 421

The biology of birds: systematics, physiology, life histories, ecology and behavior. Mr. Quay

ZO 503 (PSY 503) COMPARATIVE PSYCHOLOGY 3(3 0) S
(See psychology, page 278.)

ZO 510 ADAPTIVE BEHAVIOR OF ANIMALS 4(3-3) F
Prerequisite: ZO 421 or consent of instructor

The comparative study of animal behavior including a treatment of physiological mechanisms and adaptive significance. Both invertebrates and vertebrates are studied. Mr. Whitsett

ZO 513 (PHY 513) COMPARATIVE PHYSIOLOGY 4(2 4) S
Prerequisites: ZO 421 or consent of instructor

A comparative study of the organ systems of vertebrates and the physiological processes involved in maintaining the homeostatic state. The various compensatory mechanisms employed during environmental stress are included. Mr. Lee

ZO 515 GROWTH AND REPRODUCTION OF FISHES 3(2-3) S
Prerequisites or corequisites: GN 411, ZO 420, ZO 421, ZO 441

The biology of fishes: physiology, anatomy, pathology, behavior and genetics. This course is designed especially for graduate students in fisheries. Several trips to research laboratories are taken. (Offered in spring 1973 and alternate years.)
Mr. Pardue

ZO 517 POPULATION ECOLOGY 3(3-0) S
Prerequisites: ZO 360 (BO 360) and ST 511 or equivalent

The dynamics of natural populations. Current work, theories and problems dealing with population growth, fluctuation, limitation and patterns of dispersion, the ecological niche, food chains and energy flow. Emphasis on methods of study.
Messrs. Hayne, Davis

ZO 519 LIMNOLOGY 4(3-3) F
Prerequisite: ZO 360 (BO 360) or equivalent

A study of inland waters. Lectures dealing with physical, chemical and biologi-

cal factors that affect freshwater organisms. General principles are illustrated in the laboratory and on field trips. Mr. Hobbie

ZO 524 (PO 524) COMPARATIVE ENDOCRINOLOGY 4(3-3) S
(See poultry science, page 272.)

ZO 529 (MAS 529) BIOLOGICAL OCEANOGRAPHY 3(3-0) S
Prerequisite: ZO 360 (BO 360) or consent of instructor

A comprehensive course stressing the dynamic interrelationships between organisms of the sea and their physical and chemical environment. The latter part of the course will examine fundamental concepts in biological oceanography and will particularly stress experimental methods. Mr. Copeland

ZO 532 (GN 532) BIOLOGICAL EFFECTS OF RADIATIONS 3(3 0) S
(See genetics, page 166.)

ZO 540 (GN 540) EVOLUTION 3(3-0) F
(See genetics, page 166.)

ZO 542 HERPETOLOGY 3(2-3) S
Prerequisites: ZO 223 or ZO 351, ZO 421

The biology of the amphibians and reptiles: systematics, life history, anatomy, behavior, physiology and ecology. Mr. Martof

ZO 544 MAMMALOGY 3(2-3) S
Prerequisites: ZO 223 or ZO 351, consent of instructor

The classification, identification and ecology of the major groups of mammals. Mr. Barkalow

ZO 550 (GN 550) EXPERIMENTAL EVOLUTION 3(3-0) F
(See genetics, page 167.)

ZO 553 PRINCIPLES OF WILDLIFE SCIENCE 3(2-3) F
Prerequisite: ZO 360 (BO 360)

The principles of wildlife management and their application are studied in the laboratory and in the field. Mr. Davis

ZO 555 (MB 555) PROTOZOOLOGY 4(2-6) S
Prerequisite: Consent of instructor

The biology of the Protozoa: lectures include morphology, physiology, ecology, genetics, reproduction, evolution, systematics and life-cycles of both free-living and parasitic taxa; laboratory will stress recognition of selected forms and demonstrate techniques used to prepare specimens for microscopic examination. Mrs. Bradbury

ZO 560 (BO 560) PRINCIPLES OF ECOLOGY 4(3-3) F
Prerequisite: Three semesters of college level biology courses

A consideration of the principles of ecology at the graduate level. Each of the major subject areas of ecology is developed in sufficient depth to provide a factual and philosophical framework for the understanding of ecology. Messrs. Quay, Blum

ZO 575 (PHY 575, ENT 575) PHYSIOLOGY OF INVERTEBRATES 3(3-0) F
(See physiology, page 258.)

ZO 581 HELMINTHOLOGY 4(2 4) F
Prerequisites: ZO 223 or ZO 351, ZO 315 or equivalent

The study of the morphology, biology and control of the parasitic helminths.
Mr. Miller

ZO 582 (ENT 582) MEDICAL AND VETERINARY ENTOMOLOGY 3(2 3) S
(See entomology, page 152.)

ZO 590 SPECIAL STUDIES Credits Arranged
Prerequisites: Twelve hours zoology, consent of instructor

A directed individual investigation of a particular problem in zoology, accompanied by a review of the pertinent literature. A maximum of 3 hours is allowed toward the master's degree. Graduate Staff

ZO 592 TOPICAL PROBLEMS 1-3
Prerequisite: Consent of instructor

Organized, formal lectures and discussions of a special topic. Graduate Staff

FOR GRADUATES ONLY

ZO 603 ADVANCED PARASITOLOGY 3(2-3) S
Prerequisite: ZO 581

The study of the theoretical and practical aspects of parasitism; taxonomy, physiology and immunology of animal parasites. Messrs. Harkema, Roberts

ZO 610 CURRENT ASPECTS OF ANIMAL BEHAVIOR 4(3 3) S
Prerequisite: ZO 510 or equivalent

Lectures, discussions, seminars and laboratories. The course will treat in detail selected aspects of the behavior of invertebrates and vertebrates. The relationship of behavior to physiology, ecology and other related biological fields will be emphasized. Mr. Whitsett

ZO 614 ADVANCED CELL BIOLOGY 3(3-0) S
Prerequisite: ZO 414 (BO 414) or equivalent

A study of the current problems of cell biology including the problems of the molecular organization and functions of membrane systems, subcellular organelles and specialized cells. Messrs. Roberts, Smith

ZO 615 ADVANCED CELL BIOLOGY LAB 1(0 3) S
Prerequisite: ZO 414 (BO 414) or equivalent

The theoretical basis and utilization of techniques of cell physiology with emphasis on the principles involved, practical limitations and applications in current research. Messrs. Roberts, Smith

ZO 619 ADVANCED LIMNOLOGY 3(1 6) S
Prerequisite: ZO 519

A study of primary productivity, population interactions and effects of pollution. An experimental approach is used in the laboratory. Mr. Hobbie

ZO 621 FISHERY SCIENCE 3(2-3) F
Prerequisites: ST 511, ZO 420, a course in calculus

An analysis of fishery research methods. Population enumeration and dynamics. The relationship between fluctuations in natural populations and environmental factors. (Offered 1972-73 and alternate years.) Mr. Hassler

ZO 660 (BO 660) ADVANCED TOPICS IN ECOLOGY I 4(3-3) S

(See botany, page 85.)

ZO 661 (BO 661) ADVANCED TOPICS IN ECOLOGY II 4(3 3) S
Prerequisite: ZO 560 (BO 560) or equivalent

Reports and seminar discussions of five major topics, such as secondary productivity, competitive exclusion, predator prey and other interspecies relationships, regulation of populations, physiological ecology and management of resources. Some field trips. Laboratory provides experience in analysis of ecological systems, modeling and computer simulation. (Offered 1973 and alternate years.)

Graduate Staff

ZO 690 SEMINAR 1(1 0) FS

The presentation and defense of original research and current literature.

Graduate Staff

ZO 699 RESEARCH IN ZOOLOGY Credits Arranged
Prerequisites: Twelve hours in zoology, consent of instructor

Original research related to a student's thesis. A maximum of six hours is allowed toward the master's degree; any number toward the doctorate.

Graduate Staff

UNIVERSITY DISRUPTIONS POLICY AND PROCEDURES

A thorough and conscientious effort, which involved University trustees, administrative officers, faculty members, and student representatives, has been made to improve and clarify the University's policies and procedures for dealing with disruptive conduct. Basic to this endeavor has been the goal of preserving the right of all individuals to engage in peaceful dissent while proscribing conduct intended to obstruct or disrupt the normal operations of the University. It is sincerely believed and earnestly hoped that the results will prove to be fair and equitable to all concerned.

This policy was adopted by the duly constituted governing authorities as a part of the Code of the University of North Carolina, which now embraces all 4 year senior public institutions in North Carolina, and has the full effect of law.

POLICIES, PROCEDURES, AND DISCIPLINARY ACTIONS IN CASES OF DISRUPTION OF EDUCATIONAL PROCESS

Section 5-1. Policies Relating to Disruptive Conduct

The University of North Carolina has long honored the right of free discussion and expression, peaceful picketing and demonstrations, the right to petition and peaceably to assemble. That these rights are a part of the fabric of this institution is not questioned. They must remain secure. It is equally clear, however, that in a community of learning willful disruption of the educatonal process, destruction of property, and interference with the rights of other members of the community cannot be tolerated. Accordingly, it shall be the policy of the University to deal with any such disruption, destruction or interference promptly and effectively, but also fairly and impartially without regard to race, religion, sex or political beliefs.

Section 5-2. Definition of Disruptive Conduct

(a) Any faculty member (the term "faculty member", wherever used in this Chapter V, shall include regular faculty members, full-time instructors, lecturers, and all other persons exempt from the North Carolina State Personnel System [Chapter 126 of the General Statutes as amended] who receive compensation for teaching, or other instructional functions, or research at the University), any graduate student engaged in the instructional program, or any student who, with the intent to obstruct or disrupt any normal operation or function of the University or any of its component institutions, engages, or incites others to engage, in individual or collective conduct which destroys or significantly damages any University property, or which impairs or threatens impairment of the physical well-being of any member of the University community, or which, because of its violent, forceful, threatening or intimidating nature or because it restrains freedom of lawful movement, otherwise prevents any member of the University community from conducting his normal activities within the University, shall be subject to prompt and appropriate disciplinary action, which may include suspension, expulsion, discharge or dismissal from the University.

The following, while not intended to be exclusive, illustrate the offenses encompassed herein, when done for the purpose of obstructing or disrupting any normal operation or function of the University or any of its component institutions: (1) occupation of any University building or part thereof with intent to deprive others of its normal use; (2) blocking the entrance or exit of any University building or corridor or room therein with intent to deprive others of lawful access to or

from, or use of, said building or corridor or room; (3) setting fire to or by any other means destroying or substantially damaging any University building or property, or the property of others on University premises; (4) any possession or display of, or attempt or threat to use, for any unlawful purpose, any weapon, dangerous instrument, explosive, or inflammable material in any University building or on any University campus; (5) prevention of, or attempt to prevent by physical act, the attending, convening, continuation or orderly conduct of any University class or activity or of any lawful meeting or assembly in any University building or on any University campus; and (6) blocking normal pedestrain or vehicular traffic on or into any University campus.

(b) Any person engaged in the instructional program who fails or refuses to carry out validly assigned duties, with the intent to obstruct or disrupt any normal operation or function of the University or any of its component institution, shall be subject to prompt and appropriate disciplinary action under this Chapter V if (but only if) his status is such that he is not subject to the provisions of Section 4-3 of Chapter IV.

Section 5-3. Responsibilities of Chancellors

(a) When any Chancellor has cause to believe that any of the provisions of this Chapter V have been violated, he shall forthwith investigate or cause to be investigated the occurrence, and upon identification of the parties involved shall promptly determine whether any charge is to be made with respect thereto.

(b) If he decides that a charge is to be made, he shall, within thirty (30) days after he has information as to the identity of the alleged perpetrator of the offense but in no event more than twelve (12) months after the occurrence of the alleged offense, (i) refer the case to the appropriate existing University judicial body, or (ii) refer the matter to a Hearing Committee drawn from a previously selected Hearings Panel which, under this option, is required to implement action for violation of Section 5-2 (a) or (b) of this Chapter. If the case is referred to an existing University judicial body under (i) above, the procedural rules of the body shall be followed, and subsections (c) through (f) below shall not be applicable. If the matter is referred to a Hearing Committee under (ii) above, the procedural rules prescribed in subsections (c) through (f) below shall be followed.

(c) The accused shall be given written notice by personal service or registered mail, return receipt requested, stating:

(1) The specific violations of this Chapter V with which the accused is charged.

(2) The designated time and place of the hearing on the charge by the Hearing Committee, which time shall be not earlier than seven (7) nor later than ten (10) days following the receipt of the notice.

(3) That the accused shall be entitled to the presumption of innocence until found guilty, the right to retain counsel, the right to present the testimony of witnesses and other evidence, the right to cross-examine all witnesses against him, the right to examine all documents and demonstrative evidence adverse to him, and the right to a transcript of the proceedings of the hearing.

(d) The Hearing Committee shall determine the guilt or innocence of the accused. If the person charged is found guilty, the Hearing Committee shall recommend to the Chancellor such discipline as said body determines to be appropriate. After considering such recommendation the Chancellor shall prescribe such discipline as he deems proper. In any event, whether the person is found guilty

or not guilty a written report shall be made by the Chancellor to the President within ten (10) days.

(e) Any person found guilty shall have ten (10) days after notice of such finding in which to appeal to the President of the University. Such an appeal if taken shall be upon the grounds set forth in Section 5 5.

(f) Any accused person who, without good cause, shall fail to appear at the time and place fixed for the hearing of his case by the Hearing Committee shall be suspended indefinitely or discharged from University employment.

(g) A Chancellor, unless so ordered or otherwise prevented by court, shall not be precluded from carrying out his duties under this Chapter V by reason of any pending action in any State or Federal court. Should a delay occur in prosecuting the charge against the accused because the accused or witnesses that may be necessary to a determination of the charge are involved in State or Federal court actions, the time limitations set forth above in this Section 5 3 shall not apply.

(h) Conviction in any State or Federal court shall not preclude the University or any of its officers from exercising disciplinary action in any offense referred to in this Chapter V.

(i) Nothing contained in this Chapter V shall preclude the President or any Chancellor from taking any other steps, including injunctive relief or other legal action, which he may deem advisable to protect the best interests of the University.

Section 5-4. Aggravated Acts or Threatened Repetition of Acts

(a) The Chancellor of each of the component institutions of the University shall appoint an Emergency Consultative Panel which shall be composed of not less than three (3) nor more than five (5) faculty members and not less than three (3) nor more than five (5) students who shall be available to advise with the Chancellor in any emergency. No member of such Panel shall serve for more than one (1) year unless he be reappointed by the Chancellor. The Chancellor may make appointments, either temporary or for a full year, to fill any vacancies which may exist on the Panel.

(b) If, in the judgment of the Chancellor, there is clear and convincing evidence that a person has committed any of the acts prohibited under this Chapter V which, because of the aggravated character or probable repetition of such act or acts, necessitates immediate action to protect the University from substantial interference with any of its orderly operations or functions, or to prevent threats to or acts which endanger life or property, the Chancellor, with the concurrence as hereinafter provided of the Emergency Consultative Panel established pursuant to (a) above, may forthwith suspend such person from the University and bar him from the University campus; provided, however, that in the event of such suspension the person suspended shall be given written notice of the reason for his suspension, either personally or by registered mail addressed to his last known addresses, and shall be afforded a prompt hearing, which, if requested, shall be commenced within ten (10) days of the suspension. Except for purposes of attending personally any hearings conducted under this Chapter V, the bar against the appearance of the accused on the University campus shall remain in effect until final judgement has been rendered in his case and all appellant proceedings have been concluded, unless such restriction is earlier lifted by written notice from the Chancellor.

(c) A quorum of the Emergency Consultative Panel provided for in (a) above shall consist of not less than four (4) of its members, and the required concurrence shall have been obtained if a majority of such quorum shall indicate their con-

currence. The Chancellor shall meet personally with members of such Panel at the time he seeks concurrence, if it is feasible to do so. However, if the circumstances are such that the Chancellor deems it not to be feasible to personally assemble such members, then he may communicate with them or the required number of them individually by telephone or by such other means as he may choose to employ, in which event he may proceed as provided in (b) above after the required majority of such members have communicated their concurrence to him.

(d) In the Chancellor's absence or inability to act, the President may exercise the powers of the Chancellor specified in this Section 5-4 in the same manner and to the same extent as could the Chancellor but for such absence or inability to act.

Section 5-5. Right of Appeal

Any person found guilty of violating the provisions of this Chapter V by the Hearing Committee referred to in Section 5-3 shall have the right to appeal the finding and the discipline imposed upon him to the President of the University. Any such appeal shall be in writing, shall be based solely upon the record, and shall be limited to one or more of the following grounds:

(1) That the finding is not supported by substantial evidence;

(2) That a fair hearing was not accorded the accused; or

(3) That the discipline imposed was excessive or inappropriate.

It shall be the responsibility of the President to make prompt disposition of all such appeals, and his decision shall be rendered within thirty (30) days after receipt of the complete record on appeal.

Section 5-6. No Amnesty

No administrative official, faculty member, or student of the University shall have authority to grant amnesty or to make any promise as to prosecution or non-prosecution in any court, State or Federal, or before any student, faculty, administrative, or Trustee committee to any person charged with or suspect of violating Section 5-2 (a) or (b) of these Bylaws.

Section 5-7. Publication

The provisions of this Chapter V shall be given wide dissemination in such manner as the President or Chancellors may deem advisable, and shall be printed in the official catalogues which may be issued by each component institution of the University.

GRADUATE FACULTY*

NORTH CAROLINA STATE UNIVERSITY

ELSAYED M. AFIFY, *Visiting Associate Professor of Mechanical and Aerospace Engineering.*
Ph.D., University of Michigan.

RAUL EDUARDO ALVAREZ, *Associate Professor of Industrial Engineering.*
M.S., North Carolina State University.

MICHAEL AMEIN, *Professor of Civil Engineering.*
Ph.D., Cornell University.

CHARLES EUGENE ANDERSON, *Associate Professor of Botany.*
Ph.D., Purdue University.

CLIFTON A. ANDERSON, *Professor of Industrial Engineering and Head of the Department.*
Ph.D., Ohio State University.

DONALD BENTON ANDERSON, *Professor of Botany.*
Ph.D., Ohio State University.

NORMAN DEAN ANDERSON, *Professor of Mathematics and Science Education.*
Ph.D., Ohio State University.

ROY NELS ANDERSON, *Professor Emeritus of Education.*
Ph.D., Columbia University.

JAY LAWRENCE APPLE, *Professor of Plant Pathology, Assistant Director of Academic Affairs and Research for the Biological Sciences.*
Ph.D., North Carolina State University.

FRANK BRADLEY ARMSTRONG, *University Professor of Genetics, Microbiology and Biochemistry.*
Ph.D., University of California.

LEONARD WILLIAM AURAND, *Professor of Food Science and Biochemistry.*
Ph.D., Pennsylvania State University.

WILLIAM WYATT AUSTIN, Jr., *Professor of Metallurgical Engineering and Head of the Department of Materials Engineering.*
Ph.D., Vanderbilt University.

CHARLES WILSON AVERRE, III, *Extension Assistant Professor of Plant Pathology.*
Ph.D., Purdue University.

RICHARD CHARLES AXTELL, *Professor of Entomology.*
Ph.D., Cornell University.

ROBERT AYCOCK, *Professor of Plant Pathology and Horticultural Science.*
Ph.D., North Carolina State University.

MAHMOUD AMIN AYOUB, *Visiting Assistant Professor of Industrial Engineering.*
Ph.D., Texas Technological University.

WILLARD FARRINGTON BABCOCK, *Professor of Civil Engineering.*
S.M., Massachusetts Institute of Technology.

WALTER DEBELE BACH, JR., *Adjunct Assistant Professor of Meteorology.*
Ph.D., University of Oklahoma.

WALTER PETER BAERMANN, *Professor of Product Design.*
Ph.D., University of Munich, Germany.

DAVID CHARLES BAILEY, *Assistant Professor of History.*
Ph.D., Michigan State University.

JAMES RONALD BAILEY, *Visiting Assistant Professor of Mechanical and Aerospace Engineering.*
Ph.D., University of Southampton.

*Membership in the graduate faculty may be in either of two categories: (1) full status or (2) associate status. Full status permits a faculty member to engage in any and all phases of the graduate programs of the University. Associate members may teach courses at the graduate level and serve as chairmen of master's advisory committees.

JOHN ALBERT BAILEY, *Associate Professor of Mechanical and Aerospace Engineering.*
Ph.D., University College of Swansea.
JACK VERNON BAIRD, *Extension Professor of Soil Science.*
Ph.D., Washington State University.
BRENDA C. BALL, *Adjunct Assistant Professor of Psychology.*
Ph.D., University of North Carolina at Chapel Hill.
DAVID STAFFORD BALL, *Associate Professor of Economics.*
Ph.D., University of North Carolina at Chapel Hill.
HERSHELL RAY BALL, JR., *Assistant Professor of Food Science.*
Ph.D., University of Missouri.
WALTER ELMER BALLINGER, *Professor of Horticultural Science.*
Ph.D., Michigan State University.
WILLIAM JOHN BARCLAY, *Professor of Electrical Engineering.*
Ph.D., Stanford University.
ALDOS CORTEZ BAREFOOT, JR., *Professor Wood and Paper Science.*
D.F., Duke University.
FREDERICK SCHENCK BARKALOW, JR., *Professor of Zoology and Forestry.*
Ph.D., University of Michigan.
KENNETH REECE BARKER, *Professor of Plant Pathology.*
Ph.D., University of Wisconsin.
KEY LEE BARKLEY, *Professor Emeritus of Psychology.*
Ph.D., University of North Carolina.
ROLIN FARRAR BARRETT, *Associate Professor of Mechanical and Aerospace Engineering.*
Ph.D., North Carolina State University.
ELLIOTT ROY BARRICK, *Professor of Animal Science.*
Ph.D., Purdue University.
GEORGE TIMOTHY BARTHALMUS, *Assistant Professor of Zoology.*
Ph.D., Pennsylvania State University.
WILLIAM VICTOR BARTHOLOMEW, *Professor of Soil Science and Microbiology.*
Ph.D., Iowa State University.
PETER BATCHELOR, *Associate Professor of Urban Design.*
M.A., University of Pennsylvania.
EDWARD GUY BATTE, *Professor of Animal Science.*
D.V.M., Texas A & M University.
DAVID LEE BAYLESS, *Adjunct Assistant Professor of Statistics.*
Ph.D., Texas A & M University.
KENNETH ORION BEATTY, JR., *R. J. Reynolds Tobacco Company Professor of Chemical Engineering.*
Ph.D., University of Michigan.
JOE ROBERT BEELER, JR., *Professor of Nuclear Engineering and Materials Engineering.*
Ph.D., Kansas University.
BURTON FLOYD BEERS, *Professor of History.*
Ph.D., Duke University.
ROBERT FRANK BEHLOW, *Extension Professor of Animal Science.*
D.V.M., Ohio State University.
NORMAN ROBERT BELL, *Associate Professor of Electrical Engineering.*
M.S., Cornell University.
THOMAS ALEXANDER BELL, *Professor (USDA) of Food Science.*
M.S., North Carolina State University.
WILLARD HARRISON BENNETT, *Burlington Professor of Physics.*
Ph.D., University of Michigan.
GERALD EARL BENNINGTON, *Assistant Professor of Industrial Engineering.*
Ph.D., Johns Hopkins University.
RAY BRAMAN BENSON, JR., *Associate Professor of Metallurgical Engineering.*
Ph.D., University of California at Berkeley.
HENRY ALBERT BENT, *Professor of Chemistry.*
Ph.D., University of California at Berkeley.

RICHARD HAROLD BERNHARD, *Associate Professor of Industrial Engineering.*
Ph.D., Cornell University.
LEONIDAS JUDD BETTS, JR., *Associate Professor of English and Education.*
Ed.D., Duke University.
MARVIN KENNETH BEUTE, *Assistant Professor of Plant Pathology.*
Ph.D., Michigan State University.
BIBHUTI BHUSHAN BHATTACHARYYA, *Associate Professor of Statistics.*
Ph.D., London School of Economics.
WILLIAM LOUIS BINGHAM, *Associate Professor of Engineering Mechanics.*
Ph.D., Pennsylvania State University.
GEORGE LEE BIRELINE, JR., *Associate Professor of Design.*
M.A., University of North Carolina at Chapel Hill.
JOHN WILLIAM BISHIR, *Professor of Mathematics.*
Ph.D., North Carolina State University.
CARL THOMAS BLAKE, *Extension Professor of Crop Science.*
Ph.D., Pennsylvania State University.
PHILIP EVERETT BLANK, JR., *Associate Professor of English.*
Ph.D., University of North Carolina at Chapel Hill.
WILLIAM JOSEPH BLOCK, *Professor of Politics and Head of the Department.*
Ph.D., University of Illinois.
WILLIAM LOWRY BLOW, *Associate Professor of Poultry Science and Genetics.*
Ph.D., North Carolina State University.
UDO BLUM, *Assistant Professor of Botany.*
Ph.D., University of Oklahoma.
THOMAS NELSON BLUMER, *Professor of Food Science.*
Ph.D., Michigan State College.
JOHN FRANCIS BOGDAN, *Albert G. Myers Professor of Textiles and Acting Head of the Department of Textile Technology.*
B.T.E., Lowell Textile Institute.
JAMES RAYMOND BOHANNON, JR., *Associate Professor of Nuclear Engineering.*
M.S., North Carolina State University.
EDGAR JOHN BOONE, *Professor of Adult and Community College Education and Head of the Department and Assistant Director of Agricultural Extension Service.*
Ph.D., University of Wisconsin.
JON BORDNER, *Assistant Professor of Chemistry and Biochemistry.*
Ph.D., University of California at Berkeley.
CAREY HOYT BOSTIAN, *Professor of Genetics.*
Ph.D., University of Pittsburgh.
HENRY DITTIMUS BOWEN, *Professor of Biological and Agricultural Engineering.*
Ph.D., Michigan State University.
LAWRENCE HOFFMAN BOWEN, *Professor of Chemistry.*
Ph.D., Massachusetts Institute of Technology.
DAMON BOYNTON, *Visiting Professor of Horticulture Science.*
Ph.D., Cornell University.
PHYLLIS CLARKE BRADBURY, *Assistant Professor of Zoology.*
Ph.D., University of California at Berkeley.
JULIUS ROSCOE BRADLEY, JR., *Assistant Professor of Entomology.*
Ph.D., Louisiana State University.
CHARLES RAYMOND BRAMER, *Riddick Professor of Civil Engineering.*
E.M., Michigan College of Mining and Technology.
BARTHOLOMEW BRANDNER BRANDT, *Professor Emeritus of Zoology.*
Ph.D., Duke University.
CHARLES HENRY BRETT, *Professor of Entomology.*
Ph.D., Kansas State College.
RICHARD BRIGHT, *Professor Emeritus of Chemical Engineering.*
M.S., State University of Iowa.
CHARLES ALOYSIUS BRIM, *Professor (USDA) of Crop Science and Genetics.*
Ph.D., University of Nebraska.

ROBERT CURTIS BRISSON, *Assistant Professor of Sociology and Anthropology.*
Ph.D., North Carolina State University.
ROBERT CHARLES BROOKS, *Extension Associate Professor of Economics.*
Ph.D., Duke University.
WAYNE MAURICE BROOKS, *Associate Professor of Entomology.*
Ph.D., University of California at Berkeley.
HENRY SEAWELL BROWN, *Professor of Geosciences.*
Ph.D., University of Illinois.
MARVIN LUTHER BROWN, JR., *Professor of History.*
Ph.D., University of Pennsylvania.
PETER BROWN, *Assistant Professor of Textile Technology.*
Ph.D., Leeds University.
WILLIAM JASPER BROWN, JR., *Adjunct Assistant Professor of Agricultural Education.*
Ed.D., Pennsylvania State University.
CARL EDDINGTON BRYAN, *Research Associate in Textile Chemistry.*
Ph.D., University of Minnesota.
ROBERT SEDGWICK BRYAN, *Professor of Philosophy and Head of the Department of Philosophy and Religion.*
Ph.D., University of Virginia.
CHARLES DOUGLAS BRYANT, *Assistant Professor of Agricultural Education.*
Ed.D., Michigan State University.
J. BRUCE BULLOCK, *Assistant Professor of Economics.*
Ph.D., University of California at Davis.
ROBERTS COZART BULLOCK, *Professor of Mathematics.*
Ph.D., University of Chicago.
CARL LEE BUMGARDNER, *Professor of Chemistry.*
Ph.D., Massachusetts Institute of Technology.
HARVEY LINDY BUMGARDNER, *Professor of Poultry Science and Campus Coordinator, Peruvian Contract.*
Ph.D., University of Maryland.
STANLEY WALTER BUOL, *Professor of Soil Science.*
Ph.D., University of Wisconsin.
LAWRENCE G. BURK, *Associate Professor (USDA) of Genetics.*
M.S., University of Georgia.
ERNEST EDMUND BURNISTON, *Associate Professor of Mathematics.*
Ph.D., Birkbeck College, London.
JOSEPH CHARLES BURNS, *Associate Professor (USDA) of Crop Science.*
Ph.D., Purdue University.
ROBERT PASCHAL BURNS, JR., *Professor of Architecture and Head of the Department.*
M.Arch., Massachusetts Institute of Technology.
PETER MICHAEL BURROWS, *Visiting Assistant Professor of Statistics.*
Ph.D., North Carolina State University.
THADDEUS HILLERY BUSBICE, *Associate Professor (USDA) of Crop Science.*
Ph.D., Iowa State University.
FRED VIRGIL CAHILL, JR., *Professor of Politics.*
Ph.D., Yale University.
JOHN TYLER CALDWELL, *Professor of Politics and Chancellor.*
Ph.D., Princeton University.
KENNETH STODDARD CAMPBELL, *Professor of Textile Chemistry.*
B.S., Clemson University.
WILLIAM VERNON CAMPBELL, *Professor of Entomology.*
Ph.D., North Carolina State University.
JOHN ROBERT CANADA, *Professor of Industrial Engineering and Assistant Dean of Engineering for Extension.*
Ph.D., Georgia Institute of Technology.
THOMAS FRANKLIN CANNON, *Research Associate Professor of Horticultural Science.*
Ph.D., Ohio State University.

GEORGE LAFAYETTE CAPEL, *Extension Professor of Economics and Assistant Director of Agricultural Extension and Specialist in charge of Marketing Economics.*
Ph.D., University of Florida.

GERALD A. CARLSON, *Assistant Professor of Economics.*
Ph.D., University of California at Davis.

HALBERT HART CARMICHAEL, *Associate Professor of Chemistry.*
Ph.D., University of California at Berkeley.

WILLIAM LESTER CARPENTER, *Associate Professor of Adult and Community College Education and Head of the Department of Agricultural Information.*
Ed.D., Florida State University.

DANIEL EDWARD CARROLL, JR., *Assistant Professor of Food Science.*
Ph.D., Virginia Polytechnic Institute.

ROBERT GORDON CARSON, JR., *Professor of Industrial Engineering and Associate Dean of the School of Engineering.*
Ph.D., University of Michigan.

ROBERT JAMES CARSON, III, *Assistant Professor of Geology.*
Ph.D., University of Washington.

ROY MERWIN CARTER, *Professor of Wood and Paper Science.*
M.S., Michigan State College.

EDWARD VITANGELO CARUOLO, *Associate Professor of Animal Science.*
Ph.D., University of Minnesota.

DAVID MARSHALL CATES, *Professor of Textile Chemistry and Graduate Administrator in Textile Chemistry and Chairman of the Graduate Studies Committee for the Fiber and Polymer Science Program.*
Ph.D., Princeton University.

VICTOR VIOSCA CAVAROC, JR., *Assistant Professor of Geosciences.*
Ph.D., Louisiana State University.

THOMAS COURTNEY CAVES, *Assistant Professor of Chemistry.*
Ph.D., Columbia University.

RANDALL MARION CHAMBERS, *Adjunct Professor of Mechanical and Aerospace Engineering and Psychology.*
Ph.D., Case-Western Reserve University.

DOUGLAS SCALES CHAMBLEE, *Professor of Crop Science.*
Ph.D., Iowa State University.

LARRY STEPHEN CHAMPION, *Professor of English and Head of the Department.*
Ph.D., University of North Carolina.

RICHARD EDWARD CHANDLER, *Associate Professor of Mathematics.*
Ph.D., Florida State University.

DAVID WEBB CHANEY, *Professor of Textiles and Dean of the School.*
Ph.D., University of Pennsylvania.

CHING MING CHANG, *Assistant Professor of Engineering Mechanics.*
Dr. Ing., Technische Hochschule, Aachen.

HOU-MIN CHANG, *Assistant Professor of Wood and Paper Science.*
Ph.D., University of Washington.

TIEN-SUN CHANG, *Professor of Engineering Mechanics.*
Ph.D., University of Michigan and University of Illinois.

JAMES F. CHAPLIN, *Professor (USDA) of Crop Science and Genetics.*
Ph.D., North Carolina State University.

JOE SENTER CHAPPELL, *Associate Professor of Economics.*
Ph.D., North Carolina State University.

HARVEY JOHNSON CHARLTON, *Assistant Professor of Mathematics.*
Ph.D., Virginia Polytechnic Institute.

ALBERT LEON CHASSON, *Adjunct Associate Professor of Entomology.*
M.D., University of Cincinnati.

KWONG TUZZ CHUNG, *Assistant Professor of Physics.*
Ph.D., State University of New York at Buffalo.

JOHN G. CLAPP, JR., *Extension Assistant Professor of Crop Science.*
Ph.D., North Carolina State University.

EDGAR WILLIAM CLARK, *Adjunct Associate Professor of Entomology and Forestry.*
Ph.D., University of California at Los Angeles.
ROGER H. CLARK, *Assistant Professor of Architecture.*
M.Arch., University of Washington.
JOSEPH RAY CLARY, *Adjunct Associate Professor of Education.*
Ph.D., Ohio State University.
ALBERT J. CLAWSON, *Professor of Animal Science.*
Ph.D., Cornell University.
CARLYLE NEWTON CLAYTON, *Professor of Plant Pathology.*
Ph.D., University of Wisconsin.
MAURICE HILL CLAYTON, *Associate Professor of Engineering Mechanics.*
Ph.D., Virginia Polytechnic Institute.
WILLIAM BRAMWELL CLIFFORD, II, *Assistant Professor of Sociology and Anthropology.*
Ph.D., University of Kentucky.
GROVER CLEVELAND COBB, JR., *Associate Professor of Physics.*
Ph.D., University of Virginia.
WILLIAM YOUNTS COBB, *Adjunct Assistant Professor of Food Science.*
Ph.D., Pennsylvania State University.
HAROLD D. COBLE, *Extension Assistant Professor of Crop Science.*
Ph.D., University of Illinois.
FRED DERWARD COCHRAN, *Professor of Horticultural Science and Genetics.*
Ph.D., University of California.
COLUMBUS CLARK COCKERHAM, *Professor of Statistics and Genetics.*
Ph.D., Iowa State University.
ELOISE SNOWDEN COFER, *Extension Professor of Food Science and Assistant Director, Agricultural Extension Service (Home Economics).*
Ph.D., University of Chicago.
JAMES LAWRENCE COLE, *Associate Professor of Psychology.*
Ph.D., Duke University.
WILLIAM KERR COLLINS, *Professor of Crop Science.*
Ph.D., Iowa State University.
NEWTON VAUGHAN COLSTON, JR., *Assistant Professor of Civil Engineering.*
Ph.D., Virginia Polytechnic Institute.
NORVAL WHITE CONNER, *Professor of Mechanical and Aerospace Engineering and Assistant Dean for Research.*
M.S., Iowa State University.
MAURICE GAYLE COOK, *Professor of Soil Science.*
Ph.D., Virginia Polytechnic Institute.
ROBERT EDWARD COOK, *Professor of Poultry Science and Head of the Department.*
Ph.D., North Carolina State University.
ARMAND VINCENT COOKE, *Visiting Assistant Professor of Product Design.*
B.S.I.D., University of Cincinnati.
ARTHUR WELLS COOPER, *Professor of Botany and Forest Resources.*
Ph.D., University of Michigan.
WILLIAM DOUGLAS COOPER, *Assistant Professor of Textile Technology.*
Ph.D., North Carolina State University.
ALONZO FREEMAN COOTS, *Associate Professor of Chemistry.*
Ph.D., Vanderbilt University.
WILL ALLEN COPE, *Professor (USDA) of Crop Science and Genetics.*
Ph.D., North Carolina State University.
BILLY JOE COPELAND, *Associate Professor of Zoology and Botany.*
Ph.D., Oklahoma State University.
FREDERICK THOMAS CORBIN, *Assistant Professor of Crop Science.*
Ph.D., North Carolina State University.
FRANKLIN E. CORRELL, *Associate Professor of Horticultural Science.*
M.S., North Carolina State University.
HAROLD MAXWELL CORTER, *Professor of Psychology.*
Ph.D., Pennsylvania State University.

JOHN K. COSTER, *Professor of Agricultural Education and Director of the Center for Occupational Education.*
Ph.D., Yale University.
DONALD W. COTT, *Assistant Professor of Mechanical and Aerospace Engineering.*
Ph.D., University of Tennessee Space Institution.
ARTHUR JAMES COUTU, *Professor of Economics and Director of Peruvian Mission.*
Ph.D., North Carolina State University.
ELLIS BREVIER COWLING, *Professor of Plant Pathology, Forestry and Wood and Paper Science.*
Ph.D., University of Wisconsin.
FREDERICK RUSSELL COX, *Associate Professor of Soil Science.*
Ph.D., North Carolina State University.
GERTRUDE MARY COX, *Professor Emeritus of Experimental Statistics.*
M.S., Iowa State University.
JOSEPH H. COX, *Professor of Design.*
M.F.A., University of Iowa.
HARRIS BRADFORD CRAIG, *Professor of Food Science.*
Ph.D., Michigan State University.
PAUL DAY CRIBBINS, *Professor of Civil Engineering.*
Ph.D., Purdue University.
FORD A. CROSS, *Adjunct Assistant Professor of Zoology.*
Ph.D., Oregon State University.
JOHN ANTHONY CUCULO, *Associate Professor of Textile Chemistry.*
Ph.D., Duke University.
GEORGE AUGUST CUMMINGS, *Associate Professor of Soil Science.*
Ph.D., Purdue University.
JOSEPH WILLIAM CUNNINGHAM, *Associate Professor of Psychology.*
Ph.D., Purdue University.
JAMES ALVIN DAGGERHART, JR., *Assistant Professor of Mechanical and Aerospace Engineering.*
Ph.D., North Carolina State University.
RAGHUNATH SINGH DAHIYA, *Adjunct Assistant Professor of Food Science.*
Ph.D., North Carolina State University.
ROBERT DAVID DAHLE, *Extension Associate Professor of Economics.*
Ph.D., North Carolina State University.
JOHN MICHAEL ANTHONY DANBY, *Professor of Mathematics and Physics.*
Ph.D., Manchester University, England.
EDMUND PENDLETON DANDRIDGE, JR., *Associate Professor of English.*
Ph.D., University of Virginia.
STYLIANOS D. DANIELOPOULOS, *Assistant Professor of Computer Science.*
Ph.D., North Carolina State University.
RAYMOND BRYANT DANIELS, *Professor (USDA) of Soil Science.*
Ph.D., Iowa State University.
WALTER CARL DAUTERMAN, *Associate Professor of Entomology.*
Ph.D., University of Wisconsin.
DONALD GOULD DAVENPORT, *Associate Professor of Animal Science.*
Ph.D., Cornell University.
CHARLES BINGHAM DAVEY, *Professor of Soil Science, Forestry and Plant Pathology, and Head of the Department of Forestry.*
Ph.D., University of Wisconsin.
ADAM CLARKE DAVIS, *Professor of Sociology and Anthropology.*
Ph.D., Duke University.
DAVID EDWARD DAVIS, *Professor of Zoology and Head of the Department.*
Ph.D., Harvard University.
HENRY MAUZEE DAVIS, *Adjunct Professor of Metallurgical Engineering.*
Ph.D., University of Minnesota.
WILLIAM ROBERT DAVIS, *Professor of Physics.*
Doktor der Naturuiss, University of Hanover, Germany.

CLEBURN GILCHRIST DAWSON, *Assistant Professor of Sociology and Anthropology.*
Ph.D., North Carolina State University.
DONALD LEE DEAN, *Professor of Civil Engineering and Head of the Department.*
Ph.D., University of Michigan.
M. KEITH DEARMOND, *Associate Professor of Chemistry.*
Ph.D., University of Arizona.
FRED ROARK DEJARNETTE, *Professor of Mechanical Engineering.*
Ph.D., Virginia Polytechnic Institute.
DONALD WARREN DEJONG, *Adjunct Associate Professor of Botany.*
Ph.D., University of Georgia.
JAMES WILLIAM DICKENS, *Professor (USDA) of Biological and Agricultural Engineering.*
M.S., North Carolina State University.
EMMETT URCEY DILLARD, *Associate Professor of Animal Science and Genetics.*
Ph.D., University of Missouri.
GEORGE OSMORE DOAK, *Professor of Chemistry.*
Ph.D., University of Wisconsin.
WALTER JEROME DOBROGOSZ, *Professor of Microbiology.*
Ph.D., Pennsylvania State University.
WESLEY OSBORNE DOGGETT, *Professor of Physics.*
Ph.D., University of California at Berkeley.
ROBERT JOHN DOLAN, *Professor of Adult and Community College Education and Sociology and Anthropology.*
Ph.D., Louisiana State University.
CARL JOHN DOLCE, *Professor of Education and Dean of the School of Education.*
Ed.D., Harvard University.
WILLIAM EMMERT DONALDSON, *Professor of Poultry Science.*
Ph.D., University of Maryland.
CLIVE WELLINGTON DONOHO, JR., *Professor of Horticultural Science and Head of the Department.*
Ph.D., Michigan State University.
JESSE SEYMOUR DOOLITTLE, *Professor of Mechanical and Aerospace Engineering and Graduate Administrator.*
M.S., Pennsylvania State University.
WILLIAM GRADY DOTSON, JR., *Associate Professor of Mathematics.*
Ph.D., University of North Carolina at Chapel Hill.
ROBERT ALDEN DOUGLAS, *Professor of Engineering Mechanics and Associate Head of the Department.*
Ph.D., Purdue University.
MURRAY SCOTT DOWNS, *Associate Professor of History.*
Ph.D., Duke University.
ROBERT JACK DOWNS, *Professor of Botany and Horticultural Science.*
Ph.D., George Washington University.
LAWRENCE WILLIAM DRABICK, *Professor of Sociology and Anthropology.*
Ph.D., Pennsylvania State University.
DONALD WILLIAM DREWES, *Professor of Psychology.*
Ph.D., Purdue University.
EARL G. DROESSLER, *Administrative Dean for Research and Professor of Geosciences.*
B.A., Loras College.
JOHN WARREN DUFFIELD, *Professor of Forestry and Genetics.*
Ph.D., University of California.
ROBERT BRADFORD DUKE, *Clinical Associate Professor of Psychology.*
Ph.D., George Peabody College.
HARRY ERNEST DUNCAN, *Extension Associate Professor of Plant Pathology.*
Ph.D., West Virginia University.
JACK DAVIS DURANT, *Associate Professor of English.*
Ph.D., University of Tennessee.

EDDIE ECHANDI, *Professor of Plant Pathology.*
Ph.D., University of Wisconsin.
ARTHUR RAYMOND ECKELS, *Professor of Electrical Engineering.*
D.Engr., Yale University.
PRESTON WILLIAM EDSALL, *Professor Emeritus of Politics.*
Ph.D., Princeton University.
JOHN AUERT EDWARDS, *Professor of Engineering Mechanics.*
Ph.D., Purdue University.
EUGENE J. EISEN, *Associate Professor of Animal Science and Genetics.*
Ph.D., Purdue University.
MAGDI MOHAMED EL-KAMMASH, *Associate Professor of Economics.*
Ph.D., Duke University.
GERALD HUGH ELKAN, *Professor of Microbiology.*
Ph.D., Virginia Polytechnic Institute.
THOMAS SMITH ELLEMAN, *Professor of Nuclear Engineering and Graduate Administrator.*
Ph.D., Iowa State University.
ROBERT NEAL ELLIOTT, *Associate Professor of History.*
Ph.D., University of North Carolina at Chapel Hill.
DON EDWIN ELLIS, *Professor of Plant Pathology and Head of the Department.*
Ph.D., University of North Carolina.
ERIC LOUIS ELLWOOD, *Professor of Wood and Paper Science and Dean of the School of Forest Resources.*
Ph.D., Yale University.
SALAH E. ELMAGHRABY, *University Professor of Industrial Engineering and Operations Research.*
Ph.D., Cornell University.
ALY H. M. EL SHIEKH, *Associate Professor of Textile Technology.*
Sc.D., Massachusetts Institute of Technology.
JOHN FREDERICK ELY, *Associate Professor of Civil Engineering and Engineering Mechanics.*
Ph.D., Northwestern University.
PAUL D. EMERSON, *Associate Professor and Head, Textile Machine Design and Development*
B.S., Purdue University.
DONALD ALLEN EMERY, *Professor of Crop Science and Genetics.*
Ph.D., University of Wisconsin.
DONALD H. ENSIGN, *Associate Professor of Landscape Architecture.*
M.L.A., University of Michigan.
EDWARD WALTER ERICKSON, *Associate Professor of Economics.*
Ph.D., Vanderbilt University.
JOHN LINCOLN ETCHELLS, *Professor (USDA) of Food Science and Microbiology.*
Ph.D., Michigan State University.
JAMES BRAINERD EVANS, *Professor of Microbiology and Head of the Department.*
Ph.D., Cornell University.
RALPH EIGIL FADUM, *Professor of Civil Engineering and Dean of the School of Engineering.*
S.D., Harvard University.
ABDEL-AZIZ FAHMY, *Professor of Materials Engineering.*
Ph.D., University of Sheffield.
MAURICE HUGH FARRIER, *Professor of Entomology and Forestry.*
Ph.D., North Carolina State University.
GARY LOTTRIDGE FAULKNER, *Assistant Professor of Sociology and Anthropology.*
Ph.D., University of Georgia.
ROBERT MORCOM FEARN, *Associate Professor of Economics.*
Ph.D., University of Chicago.
RICHARD MARK FELDER, *Assistant Professor of Chemical Engineering.*
Ph.D., Princeton University.

JAMES K. FERRELL, *Alcoa Professor of Chemical Engineering and Head of the Department.*
Ph.D., North Carolina State University.

WILLIAM THOMAS FIKE, JR., *Associate Professor of Crop Science.*
Ph.D., University of Minnesota.

ALVA LEROY FINKNER, *Adjunct Professor of Statistics.*
Ph.D., North Carolina State University.

LAWRENCE FISHBEIN, *Adjunct Professor of Entomology and Toxicology.*
Ph.D., Georgetown University.

CHARLES PAGE FISHER, JR., *Adjunct Associate Professor of Civil Engineering.*
Ph.D., North Carolina State University.

ROGER CARL FITES, *Assistant Professor of Botany.*
Ph.D., University of Illinois.

JAMES WALTER FITTS, *Professor of Soil Science, and Coordinator AID Latin American Soil Testing Project.*
Ph.D., Iowa State College.

HENRY PRIDGEN FLEMING, *Associate Professor (USDA) of Food Science.*
Ph.D., University of Illinois.

WALTER A. FLOOD, *Professor of Electrical Engineering.*
Ph.D., Cornell University.

VINCENT M. FOOTE, *Associate Professor of Product Design and Acting Head of the Department.*
B.S., University of Cincinnati.

ROBERT JOSEPH FORNARO, *Assistant Professor of Computer Science.*
Ph.D., Pennsylvania State University.

RAYMOND EARL FORNES, *Assistant Professor of Textiles and Physics.*
Ph.D., North Carolina State University.

BENJAMIN EAGLES FOUNTAIN, *Adjunct Professor of Adult and Community College Education.*
Ph.D., University of North Carolina at Chapel Hill.

JAMES R. FOUTS, *Adjunct Professor of Entomology.*
Ph.D., Northwestern University.

LEON DAVID FREEDMAN, *Professor of Chemistry.*
Ph.D., Johns Hopkins University.

RONALD OWEN FULP, *Associate Professor of Mathematics.*
Ph.D., Auburn University.

A. RONALD GALLANT, *Visiting Assistant Professor of Economics and Statistics.*
Ph.D., Iowa State University.

WILLIAM SYLVAN GALLER, *Associate Professor of Civil Engineering.*
Ph.D., Northwestern University.

GENE JOHN GALLETTA, *Professor of Horticultural Science and Genetics.*
Ph.D., University of California at Berkeley.

BERTRAM HOWARD GARCIA, JR., *Professor of Mechanical and Aerospace Engineering.*
Ph.D., Virginia Polytechnic Institute.

BRUCE LYNN GARDNER, *Assistant Professor of Economics.*
Ph.D., University of Chicago.

ROBIN PIERCE GARDNER, *Professor of Nuclear Engineering and Chemical Engineering.*
Ph.D., Pennsylvania State University.

THOMAS DEAN GARDNER, *Assistant Professor of Psychology.*
Ph.D., George Peabody College.

JIM DALE GARLICH, *Assistant Professor of Poultry Science.*
Ph.D., Cornell University.

DENNIS EVO GAROUTTE, *Assistant Professor of Mathematics.*
Ph.D., Montana State University.

JAMES WADE GAULT, *Assistant Professor of Electrical Engineering.*
Ph.D., University of Iowa.

DAVID WILLIAM GAYLOR, *Adjunct Associate Professor of Statistics.*
Ph.D., North Carolina State University.

ROBERT P. GECKLER, *Research Associate in Statistics.*
Ph.D., Indiana University.
RALPH GELLAR, *Assistant Professor of Mathematics.*
Ph.D., Columbia University.
JAMES DALTON GEORGE, *Extension Professor of Sociology and Anthropology and Adult and Community College Education.*
Ph.D., Florida State University.
THOMAS WALLER GEORGE, *Associate Professor of Textile Technology.*
M.A., University of Illinois.
THOMAS MICHAEL GERIG, *Assistant Professor of Statistics.*
Ph.D., University of North Carolina.
DAN ULRICH GERSTEL, *William Neal Reynolds Professor of Crop Science and Genetics.*
Ph.D., University of California.
FORREST WILLIAM GETZEN, *Associate Professor of Chemistry.*
Ph.D., Massachusetts Institute of Technology.
FRANCIS GERHARD GIESBRECHT, *Associate Professor of Statistics.*
Ph.D., Iowa State University.
RICHARD DEAN GILBERT, *Professor of Textile Chemistry.*
Ph.D., University of Notre Dame.
WILLIAM BEST GILBERT, *Associate Professor of Crop Science.*
Ph.D., North Carolina State University.
JAMES WENDELL GILLIAM, *Associate Professor of Soil Science.*
Ph.D., Mississippi State University.
STANLEY EUGENE GILLILAND, *Assistant Professor of Food Science.*
Ph.D., North Carolina State University.
JOSEPH CONRAD GLASS, JR., *Assistant Professor of Adult and Community College Education.*
Ed.D., North Carolina State University.
EDWARD WALKER GLAZENER, *Professor of Poultry Science and Genetics and Director of Academic Affairs, School of Agriculture and Life Sciences.*
Ph.D., University of Maryland.
CHESTER EUGENE GLEIT, *Associate Professor of Chemistry.*
Ph.D., Massachusetts Institute of Technology.
TILDON H. GLISSON, JR., *Assistant Professor of Electrical Engineering.*
Ph.D., Southern Methodist University.
ALFRED JOHN GOETZE, *Associate Professor of Electrical Engineering.*
Ph.D., Duke University.
RAYMOND PAUL GOGOLEWSKI, *Assistant Professor of Engineering Mechanics.*
Ph.D., Cornell University.
HARVEY JOSEPH GOLD, *Associate Professor of Statistics and Animal Science.*
Ph.D., University of Wisconsin.
GEORGE GOLDFINGER, *Professor of Textile Chemistry.*
Ph.D., University of Paris.
IRVING S. GOLDSTEIN, *Professor of Wood and Paper Science and Head of the Department.*
Ph.D., Harvard University.
LEMUEL GOODE, *Professor of Animal Science.*
Ph.D., University of Florida.
GUY VERNON GOODING, JR., *Associate Professor of Plant Pathology.*
Ph.D., University of California at Davis.
MAJOR M. GOODMAN, *Associate Professor of Statistics and Genetics.*
Ph.D., North Carolina State University.
GILBERT GOTTLIEB, *Adjunct Associate Professor of Psychology.*
Ph.D., Duke University.
CHRISTOPHER R. GOULD, *Assistant Professor of Physics.*
Ph.D., University of Pennsylvania.
WILLIAM LEE GRAGG, *Associate Professor of Adult and Community College Education.*
Ph.D., Cornell University.

LOUIS A. GRAHAM, *Adjunct Assistant Professor of Textile Chemistry.*
M.Ch.E., University of Virginia.

ROBERT WILLIAM GRAHAM, *Adjunct Professor of Mechanical and Aerospace Engineering.*
Ph.D., Purdue University.

LARRY FRANK GRAND, *Associate Professor of Plant Pathology and Forestry.*
Ph.D., Washington State University.

ARNOLD HERBERT EDWARD GRANDAGE, *Professor of Statistics.*
Ph.D., North Carolina State University.

JOSEF STEFAN GRATZL, *Associate Professor of Wood and Paper Science.*
Ph.D., University of Vienna.

RALPH WELLER GREENLAW, *Professor of History and Head of the Department.*
Ph.D., Princeton University.

WALTON CARLYLE GREGORY, *William Neal Reynolds Professor of Crop Science and Genetics.*
Ph.D., University of Virginia.

DANIEL SWARTWOOD GROSCH, *Professor of Genetics and Zoology.*
Ph.D., University of Pennsylvania.

HARRY DOUGLASS GROSS, *Professor of Crop Science.*
Ph.D., Iowa State University.

THOMAS HYMAN GUION, *Associate Professor of Textile Chemistry.*
Ph.D., University of North Carolina.

BHUPENDER SINGH GUPTA, *Assistant Professor of Textile Technology.*
Ph.D., Manchester College of Science and Technology, Manchester, England.

EDWARD DEWITT GURLEY, *Associate Professor of Engineering Mechanics.*
Ph.D., University of Illinois.

FRANK EDWIN GUTHRIE, *Professor of Entomology.*
Ph.D., University of Illinois.

GEORGE RICHARD GWYNN, *Associate Professor (USDA) of Crop Science and Genetics.*
Ph.D., Iowa State University.

ROBERT JOHN HADER, *Professor of Statistics.*
Ph.D., North Carolina State University.

WILLIAM LEROY HAFLEY, *Associate Professor of Forestry and Statistics.*
Ph.D., North Carolina State University.

FRANCIS JOSEPH HALE, *Professor of Mechanical and Aerospace Engineering.*
Sc.D., Massachusetts Institute of Technology.

ROBERT GORDON HALFACRE, *Associate Professor of Horticultural Science.*
Ph.D., Virginia Polytechnic Institute.

GEORGE LINCOLN HALL, *Professor of Physics.*
Ph.D., University of Virginia.

MAX HALPEREN, *Associate Professor of English.*
Ph.D., Florida State University.

DONALD DALE HAMANN, *Associate Professor of Food Science and Biological and Agricultural Engineering.*
Ph.D., Virginia Polytechnic Institute.

DAME SCOTT HAMBY, *Burlington Industries Professor of Textile Technology and Director of Textiles Extension and Continuing Education.*
B.S., Alabama Polytechnic Institute.

CHARLES HORACE HAMILTON, *William Neal Reynolds Professor Emeritus of Sociology and Anthropology.*
Ph.D., University of North Carolina.

PAT BROOKS HAMILTON, *Professor of Poultry Science and Microbiology.*
Ph.D., University of Wisconsin.

JOHN VALENTINE HAMME, *Associate Professor of Ceramic Engineering and Director of Cooperative Engineering Education.*
Ph.D., North Carolina State University.

GORDON A. HAMMON, *Associate Professor of Recreation Resources Administration.*
B.S., New York State College of Forestry.

LEIGH HUGH HAMMOND, *Extension Associate Professor of Economics.*
Ph.D., North Carolina State University.
KENNETH WILLIAM HANCK, *Assistant Professor of Chemistry.*
Ph.D., University of Illinois.
ARTHUR PAUL HANSEN, *Assistant Professor of Food Science.*
Ph.D., Pennsylvania State University.
DONALD JOSEPH HANSEN, *Assistant Professor of Mathematics.*
Ph.D., University of Texas.
DURWIN MELFORD HANSON, *Professor of Industrial and Technical Education and Head of the Department.*
Ph.D., Iowa State University.
JAMES WILLIAM HANSON, *Assistant Professor of Computer Science.*
M.A., University of Michigan.
WARREN DURWARD HANSON, *Professor of Genetics.*
Ph.D., Purdue University.
JOHN J. HARDER, *Associate Professor of Industrial Engineering.*
Dr. Ing., Technische Hochschule, Hanover, Germany.
JAMES WALKER HARDIN, *Professor of Botany and Forest Resources.*
Ph.D., University of Michigan.
REINARD HARKEMA, *Professor of Zoology.*
Ph.D., Duke University.
CLEON WALLACE HARRELL, JR., *Associate Professor of Economics.*
M.A., University of Virginia.
GEORGE OLIVER HARRELL, *Associate Professor of Materials Engineering.*
Ph.D., Ohio State University.
WALTER JOEL HARRINGTON, *Professor of Mathematics.*
Ph.D., Cornell University.
HARWELL HAMILTON HARRIS, *Professor of Architecture.*
JAMES RAY HARRIS, *Extension Professor of Poultry Science.*
D.V.M., Auburn University.
WILLIAM CHARLES HARRIS, *Associate Professor of History.*
Ph.D., University of Alabama.
CLARENCE ARTHUR HART, *Professor of Wood and Paper Science.*
Ph.D., North Carolina State University.
FRANKLIN DELANO HART, *Professor of Mechanical and Aerospace Engineering.*
Ph.D., North Carolina State University.
LODWICK CHARLES HARTLEY, *Professor Emeritus of English.*
Ph.D., Princeton University.
ROBERT EDUARD HARTWIG, *Assistant Professor of Mathematics.*
Ph.D., University of Adelaide.
PAUL HENRY HARVEY, *William Neal Reynolds Professor of Crop Science and Genetics and Head of the Department of Crop Science.*
Ph.D., Iowa State University.
RAYMOND W. HARVEY, *Associate Professor of Animal Science.*
Ph.D., North Carolina State University.
HASSAN AHMED HASSAN, *Professor of Mechanical and Aerospace Engineering.*
Ph.D., University of Illinois.
FRANCIS JEFFERSON HASSLER, *William Neal Reynolds Professor of Biological and Agricultural Engineering and Head of the Department.*
Ph.D., Michigan State College.
WILLIAM WALTON HASSLER, *Professor of Zoology.*
Ph.D., University of Tennessee.
JOHN REID HAUSER, *Associate Professor of Electrical Engineering.*
Ph.D., Duke University.
KERRY SHUFORD HAVNER, *Associate Professor of Civil Engineering.*
Ph.D., Oklahoma State University.
EDWARD CHARLES HAYES, III, *Assistant Professor of Microbiology.*
Ph.D., Rutgers University.

DON WILLIAM HAYNE, *Professor of Statistics and Zoology.*
Ph.D., University of Michigan.
FRANK LLOYD HAYNES, JR., *Professor of Horticultural Science and Genetics.*
Ph.D., Cornell University.
WILLIAM JOSEPH HEAD, *Assistant Professor of Civil Engineering.*
Ph.D., Purdue University.
ALLEN STREETER HEAGLE, *Adjunct Assistant Professor of Plant Pathology.*
Ph.D., University of Minnesota.
TEDDY THEODORE HEBERT, *Professor of Plant Pathology and Genetics.*
Ph.D., North Carolina State University.
WALTER WEBB HECK, *Adjunct Professor of Botany.*
Ph.D., University of Illinois.
GENE HEDGE, *Assistant Professor of Product Design.*
B.S., Illinois Institute of Technology.
CLINTON LOUIS HEIMBACH, *Professor of Civil Engineering.*
Ph.D., University of Michigan.
WARREN ROBERT HENDERSON, *Associate Professor of Horticultural Science.*
Ph.D., Ohio State University.
FORREST CLYDE HENTZ, JR., *Associate Professor of Chemistry.*
Ph.D., University of North Carolina.
GEORGE HENRY HEPTING, *Adjunct Professor of Plant Pathology and Forestry.*
Ph.D., Cornell University.
SOLOMON PHILIP HERSH, *Professor of Textile Technology and Graduate Administrator.*
Ph.D., Princeton University.
CHARLES HORACE HILL, *Professor of Poultry Science and Animal Science.*
Ph.D., Cornell University.
THOMAS IRA HINES, *Professor of Recreation Resources Administration and Head of the Department.*
M.A., University of North Carolina.
ROBERT GRANT HITCHINGS, *Professor and In Charge of Pulp and Paper Science and Technology.*
M.F., Duke University.
GEORGE BURNHAM HOADLEY, *Professor of Electrical Engineering and Head of the Department.*
D.Sc., Massachusetts Institute of Technology.
JOHN EYRES HOBBIE, *Professor of Zoology.*
Ph.D., Indiana University.
JOSEPH PATRICK HOBBS, *Assistant Professor of History.*
Ph.D., Johns Hopkins University.
CHARLES SASNETTE HODGES, JR., *Professor (USDA) of Plant Pathology and Forestry.*
Ph.D., University of Georgia.
ERNEST HODGSON, *Professor of Entomology.*
Ph.D., Oregon State University.
HAROLD DOUGLAS HOLDER, *Visiting Associate Professor of Sociology and Anthropology.*
Ph.D., Syracuse University.
DANIEL LESTER HOLLEY, JR., *Assistant Professor of Wood and Paper Science and Economics.*
Ph.D., North Carolina State University.
ROBERT GRIFFEN HOLMES, *Associate Professor of Biological and Agricultural Engineering.*
Ph.D., Ohio State University.
ABRAHAM HOLTZMAN, *Professor of Politics.*
Ph.D., Harvard University.
THOMAS LYNN HONEYCUTT, *Assistant Professor of Computer Science.*
Ph.D., North Carolina State University.
DALE MAX HOOVER, *Professor of Economics.*
Ph.D., University of Chicago.

MAURICE WILLIAM HOOVER, *Professor of Food Science.*
Ph.D., University of Florida.

HAROLD BRUCE HOPFENBERG, *Associate Professor of Chemical Engineering.*
Ph.D., Massachusetts Institute of Technology.

WILLIAM ERNEST HOPKE, *Professor of Guidance and Personnel Services and Head of the Department.*
Ed.D., Teachers College, Columbia University.

YASUKUKI HORIE, *Assistant Professor of Engineering Mechanics.*
Ph.D., Washington State University.

JOHN WILLIAM HORN, *Professor of Civil Engineering.*
M.S.C.E., Massachusetts Institute of Technology.

HORACE ROBERT HORTON, *Associate Professor of Biochemistry.*
Ph.D., University of Missouri.

DANIEL GOODMAN HORVITZ, *Adjunct Professor of Statistics.*
Ph.D., Iowa State University.

DAVID HEWES HOWELLS, *Professor of Biological and Agricultural Engineering and Director of Water Resources Research Institute.*
M.S., Massachusetts Institute of Technology.

BARNEY KUO-YEN HUANG, *Associate Professor of Biological and Agricultural Engineering.*
Ph.D., Purdue University.

NORDEN EH HUANG, *Assistant Professor of Oceanography.*
Ph.D., Johns Hopkins University.

Z ZIMMERMAN HUGUS, JR., *Professor of Chemistry and Head of the Department.*
Ph.D., University of California at Berkeley.

DONALD HUISINGH, *Associate Professor of Plant Pathology.*
Ph.D., University of Wisconsin.

FRANK JAMES HUMENIK, *Assistant Professor of Biological and Agricultural Engineering and Civil Engineering.*
Ph.D., Ohio State University.

ERVIN GRIGG HUMPHRIES, *Associate Professor of Biological and Agricultural Engineering and Engineering Mechanics.*
Ph.D., North Carolina State University.

JAMES ERNEST HUNEYCUTT, JR., *Assistant Professor of Mathematics.*
Ph.D., University of North Carolina at Chapel Hill.

ARVEL HATCH HUNTER, *Visiting Associate Professor of Soil Science.*
Ph.D., North Carolina State University.

JOHN CALVIN HURT, *Assistant Professor of Materials Engineering.*
Ph.D., Rutgers University.

GEORGE HYATT, JR., *Professor of Animal Science and Director of Agricultural Extension Service.*
Ph.D., University of Wisconsin.

LOREN ALBERT IHNEN, *Professor of Economics.*
Ph.D., Iowa State University.

JOHN E. IKERD, *Extension Assistant Professor of Economics.*
Ph.D., University of Missouri.

MAKOTO ITOH, *Visiting Professor of Mathematics.*
Ph.D., Hiroshima University.

WILLIAM ADDISON JACKSON, *Professor of Soil Science.*
Ph.D., North Carolina State University.

HERMAN BROOKS JAMES, *Vice president of Research/Public Service Programs, University of North Carolina and Professor of Economics, NCSU.*
Ph.D., Duke University.

ALVIN WILKINS JENKINS, JR., *Professor of Physics.*
Ph.D., University of Virginia.

JOHN MITCHELL JENKINS, JR., *Research Professor of Horticultural Science.*
Ph.D., University of Minnesota.

SAMUEL FOREST JENKINS, JR., *Associate Professor of Plant Pathology.*
Ph.D., North Carolina State University.
BOBBY RAY JOHNSON, *Assistant Professor of Food Science.*
Ph.D., Oklahoma State University.
BRYAN HUGH JOHNSON, *Assistant Professor of Animal Science.*
Ph.D., Oklahoma State University.
FRANKLIN M. JOHNSON, *Assistant Professor of Genetics.*
Ph.D., University of Texas.
JOSEPH CLYDE JOHNSON, *Professor of Psychology.*
Ed.D., George Peabody College for Teachers.
PAUL REYNOLDS JOHNSON, *Professor of Economics.*
Ph.D., University of Chicago.
WILLIAM HUGH JOHNSON, *Professor of Biological and Agricultural Engineering.*
Ph.D., North Carolina State University.
WILLIAM L. JOHNSON, *Assistant Professor of Animal Science.*
Ph.D., Cornell University.
DONALD R. JOHNSTON, *Environmental Engineering Extension Specialist.*
MSPH, University of North Carolina at Chapel Hill.
CHARLES PARKER JONES, *Assistant Professor of Economics.*
Ph.D., University of North Carolina.
EDGAR WALTON JONES, *Associate Professor of Economics and Acting Dean for University Extension.*
Ph.D., North Carolina State University.
EVAN EARL JONES, *Associate Professor of Animal Science and Biochemistry.*
Ph.D., University of Illinois.
GUY LANGSTON JONES, *Professor of Crop Science and Soil Science.*
Ph.D., University of Minnesota.
HOUSTON GWYNNE JONES, *Adjunct Professor of History.*
Ph.D., Duke University.
IVAN DUNLAVY JONES, *Professor Emeritus of Food Science.*
Ph.D., University of Minnesota.
JAMES ROBERT JONES, *Extension Associate Professor of Animal Science.*
Ph.D., Cornell University.
LAWRENCE KEITH JONES, *Assistant Professor of Guidance and Personnel Services.*
Ph.D., University of Missouri.
LOUIS ALLMAN JONES, *Associate Professor of Chemistry.*
Ph.D., Texas A&M University.
VICTOR ALAN JONES, *Associate Professor of Food Science and Biological and Agricultural Engineering.*
Ph.D., Michigan State University.
JOSEPH STEPHAN KAHN, *Professor of Botany and Biochemistry.*
Ph.D., University of Illinois.
AMIN M. KAMAL, *Associate Professor of Industrial Engineering.*
Ph.D., Nottingham University.
HENRY LEVEKE KAMPHOEFNER, *Professor of Architecture and Dean of the School of Design.*
M.S. Arch., Columbia University.
EUGENE JOHN KAMPRATH, *Professor of Soil Science.*
Ph.D., North Carolina State University.
ABDEL-AZIZ ISMAIL KASHEF, *Professor of Civil Engineering.*
Ph.D., Purdue University.
GERALD HOWARD KATZIN, *Associate Professor of Physics.*
Ph.D., North Carolina State University.
JAMES F. KAUFFMAN, *Assistant Professor of Electrical Engineering.*
Ph.D., North Carolina State University.
HARVEY G. KEBSCHULL, *Associate Professor of Politics.*
Ph.D., University of Illinois.
KENNETH RAYMOND KELLER, *Professor of Crop Science and Assistant Director of Research, School of Agriculture and Life Sciences.*
Ph.D., Iowa State University.

ROBERT CLAY KELLISON, *Assistant Professor of Forestry.*
Ph.D., North Carolina State University.
HARRY CHARLES KELLY, *Professor of Physics and Vice Chancellor and Provost.*
Ph.D., Massachusetts Institute of Technology.
HENDERSON GRADY KINCHELOE, *Professor of English.*
Ph.D., Duke University.
DORIS ELIZABETH KING, *Professor of History.*
Ph.D., Duke University.
RICHARD ADAMS KING, *M. G. Mann Professor of Economics.*
Ph.D., Harvard University.
JAMES BRYANT KIRKLAND, *Professor of Education and Dean Emeritus of the School of Education.*
Ph.D., Ohio State University.
PEDER JOHAN KLEPPE, *Adjunct Associate Professor of Wood and Paper Science.*
Dr. Rer. Nat., Technical University of Darmstadt.
DAVID MCKENDREE KLINE, *Professor (USDA) of Plant Pathology.*
Ph.D., University of Wisconsin.
WESLEY EDWIN KLOOS, *Associate Professor of Genetics and Microbiology.*
Ph.D., Iowa State University.
DAVID RAYMOND KNIEFEL, *Assistant Professor of Education.*
Ed.D., New Mexico State University.
KENNETH LEE KNIGHT, *Professor of Entomology and Head of the Department.*
Ph.D., University of Illinois.
RICHARD BENNETT KNIGHT, *L. L. Vaughan Professor of Mechanical and Aerospace Engineering.*
M.S., University of Illinois.
JAMES ARTHUR KNOPP, *Assistant Professor of Biochemistry.*
Ph.D., University of Illinois.
ALBERT SIDNEY KNOWLES, *Associate Professor of English.*
M.A., University of Virginia.
CHARLES ERNEST KNOWLES, *Assistant Professor of Geosciences.*
Ph.D., Texas A&M University.
JEROME WILLIAM KOENIGS, *Adjunct Associate Professor of Forestry and Plant Pathology.*
Ph.D., Washington State University.
KWANGIL KOH, *Professor of Mathematics.*
Ph.D., University of North Carolina at Chapel Hill.
JOHN RONALD KOLB, *Associate Professor of Mathematics and Mathematics and Science Education.*
Ph.D., University of Maryland.
THOMAS RHINEHART KONSLER, *Associate Professor of Horticultural Science.*
Ph.D., North Carolina State University.
BENJAMIN GRANADE KOONCE, JR., *Professor of English.*
Ph.D., Princeton University.
WILLIAM WURTH KRIEGEL, *Professor Emeritus of Ceramic Engineering.*
Dr. Ing., Technische Hochschule, Hanover, Germany.
GEORGE JAMES KRIZ, *Associate Professor of Biological and Agricultural Engineering and Associate Department Head in Charge of Extension.*
Ph.D., University of California at Davis.
ELMER GEORGE KUHLMAN, *Adjunct Associate Professor of Plant Pathology and Forestry.*
Ph.D., Oregon State University.
LEATON JOHN KUSHMAN, *Professor (USDA) of Horticultural Science.*
M.S., George Washington University.
FRED LADO, JR., *Assistant Professor of Physics.*
Ph.D., University of Florida.
JOHN RALPH LAMBERT, JR., *Professor of University Studies & Acting Head of the Division.*
Ph.D., Princeton University.

JOE OSCAR LAMMI, *Professor of Forestry.*
Ph.D., University of California at Berkeley.
FORREST WESLEY LANCASTER, *Professor Emeritus of Physics.*
Ph.D., Duke University.
CHESTER GREY LANDES, *Associate Professor of Wood and Paper Science.*
B.S.Ch.E., Ohio State University.
LEONARD JAY LANGFELDER, *Associate Professor of Civil Engineering.*
Ph.D., University of Illinois.
ROY AXEL LARSON, *Professor of Horticultural Science.*
Ph.D., Cornell University.
CHARLES JAMES LAW, JR., *Adjunct Assistant Professor of Adult and Community College Education.*
Ed.D., Duke University.
JAMES MURRAY LEATHERWOOD, *Professor of Animal Science.*
Ph.D., North Carolina State University.
JAMES GIACOMO LECCE, *Professor of Animal Science and Microbiology.*
Ph.D., University of Pennsylvania.
THOMAS BENSON LEDBETTER, *Assistant Professor of Mechanical and Aerospace Engineering.*
M.S., North Carolina State University.
DOUGLAS HARRY KEDGWIN LEE, *Adjunct Professor of Zoology.*
D.T.M., University of Sydney.
JOSHUA ALEXANDER LEE, *Professor (USDA) of Crop Science and Genetics.*
Ph.D., University of California at Davis.
JAMES EDWARD LEGATES, *William Neal Reynolds Professor of Animal Science and Dean of the School of Agriculture and Life Sciences.*
Ph.D., Iowa State University.
SAMUEL GEORGE LEHMAN, *Professor Emeritus of Plant Pathology.*
Ph.D., Washington University.
CARLTON JAMES LEITH, *Professor of Geosciences and Head of the Department.*
Ph.D., University of California at Berkeley.
KURT JOHN LEONARD, *Assistant Professor (USDA) of Plant Pathology.*
Ph.D., Cornell University.
GERALD S. LEVENTHAL, *Adjunct Associate Professor of Psychology.*
Ph.D., Duke University.
THOMAS EARL LEVERE, *Assistant Professor of Psychology.*
Ph.D., Ohio State University.
MICHAEL PHILLIP LEVI, *Associate Professor of Plant Pathology and Wood and Paper Science.*
Ph.D., Leeds University.
JACK LEVINE, *Professor of Mathematics.*
Ph.D., Princeton University.
SAMUEL GALE LEVINE, *Professor of Chemistry.*
Ph.D., Harvard University.
CHARLES SANFORD LEVINGS, III, *Associate Professor of Genetics.*
Ph.D., University of Illinois.
CHARLES EDWARD LEWIS, *Extension Assistant Professor of Sociology and Anthropology.*
Ph.D., North Carolina State University.
HAROLD LOYD LEWIS, *Adjunct Associate Professor of Botany and Microbiology.*
Ph.D., University of Arkansas.
PAUL EDWIN LEWIS, *Professor of Mathematics and Head of the Department of Computer Science.*
Ph.D., University of Illinois.
WILLIAM MASON LEWIS, *Professor of Crop Science.*
Ph.D., University of Minnesota.
DAVID ALAN LINK, *Associate Professor of Computer Science and Administrative Assistant to the Department Head.*
Ph.D., Iowa State University.

ARDELL CHESTER LINNERUD, *Assistant Professor of Statistics.*
Ph.D., University of Minnesota.
MICHAEL ANTHONY LITTLEJOHN, *Associate Professor of Electrical Engineering.*
Ph.D., North Carolina State University.
ROBERT WARREN LLEWELLYN, *Professor of Industrial Engineering.*
M.S.I.E., Purdue University.
RICHARD HENRY LOEPPERT, *Professor of Chemistry and Assistant to the Department Head.*
Ph.D., University of Minnesota.
GEORGE GILBERT LONG, *Professor of Chemistry.*
Ph.D., University of Florida.
RAYMOND CARL LONG, *Assistant Professor of Crop Science.*
Ph.D., University of Illinois.
IAN STEWART LONGMUIR, *Professor of Biochemistry.*
M.B.B., St. Bartholomew's Medical School, London.
PETER REEVES LORD, *Associate Professor of Textile Technology.*
Ph.D., University of London.
RICHARD LAWRENCE LOWER, *Associate Professor of Horticulture Science.*
Ph.D., University of Illinois.
ROBERT E. LUBOW, *Professor of Psychology.*
Ph.D., Cornell University.
GEORGE BLANCHARD LUCAS, *Professor of Plant Pathology.*
Ph.D., Louisiana State University.
HENRY LAWRENCE LUCAS, JR., *William Neal Reynolds Professor of Statistics.*
Ph.D., Cornell University.
LEON THOMAS LUCAS, *Assistant Professor of Plant Pathology.*
Ph.D., University of California at Davis.
JAMES EMORY ROBINSON LUGINBUHL, *Assistant Professor of Psychology.*
Ph.D., University of North Carolina at Chapel Hill.
JIANG LUH, *Professor of Mathematics.*
Ph.D., University of Michigan.
DAN BARRY LUMSDEN, *Assistant Professor of Adult and Community College Education and Director of the Adult Learning Resources Center.*
Ed.D., North Carolina State University.
JAMES FULTON LUTZ, *Professor of Soil Science.*
Ph.D., University of Missouri.
JOHN LYMAN, *Professor of Oceanography.*
Ph.D., University of California at Los Angeles.
JOSEPH THOMAS LYNN, *Professor of Physics and Graduate Administrator and Administrative Assistant to the Department Head.*
M.S., Ohio State University.
CHARLES F. LYTLE, *Associate Professor of Zoology and Teaching Coordinator in the Biological Sciences.*
Ph.D., Indiana University.
JERRY LEE MACHEMEHL, *Assistant Professor of Civil Engineering.*
Ph.D., Texas A&M University.
HARRY ARENDT MACKIE, *Associate Professor of Product Design.*
B.S., Louisiana State University.
CLARENCE JOSEPH MADAY, *Associate Professor of Engineering Mechanics.*
Ph.D., Northwestern University.
JAMES GRAY MADDOX, *Professor of Economics.*
Ph.D., Harvard University.
MICHAEL JAY MAGAZINE, *Assistant Professor of Industrial Engineering.*
Ph.D., University of Florida.
JOHN WILLIAM MAGILL, *Associate Professor of Psychology.*
Ph.D., University of Pittsburgh.
JAMES KITCHENER MAGOR, *Professor of Materials Engineering.*
Ph.D., Pennsylvania State University.

ALEXANDER RUSSELL MAIN, *Professor of Biochemistry.*
Ph.D., Cambridge University, England.
CHARLES EDWARD MAIN, *Assistant Professor of Plant Pathology.*
Ph.D., University of Wisconsin.
CHARLES MICHAEL MAINLAND, *Extension Assistant Professor of Horticultural Science.*
Ph.D., Rutgers University.
T. EWALD MAKI, *Carl Alwin Schenck Professor of Forestry.*
Ph.D., University of Minnesota.
EUGENE FRANCIS MALESKI, *Visiting Assistant Professor of Psychology.*
Ph.D., University of Nebraska.
FRED ALLEN MANGUM, JR., *Associate Professor of Economics.*
Ph.D., Michigan State University.
CARROLL LAMB MANN, JR., *Adjunct Professor of Civil Engineering.*
C.E., Princeton University.
THURSTON JEFFERSON MANN, *Professor of Crop Science and Genetics and Head of the Department of Genetics.*
Ph.D., Cornell University.
CHARLES RICHARD MANNING, JR., *Associate Professor of Materials Engineering.*
Ph.D., North Carolina State University.
EDWARD GEORGE MANNING, *Associate Professor of Electrical Engineering.*
M.S., North Carolina State University.
EDWARD RAYMOND MANRING, *Professor of Physics.*
Ph.D., Ohio State University.
ALLISON RAY MANSON, *Associate Professor of Statistics.*
Ph.D., Virginia Polytechnic Institute.
WILLIAM PAUL MARLEY, *Assistant Professor of Physical Education.*
Ph.D., University of Toledo.
HERMAN F. MARK, *Adjunct Professor of Textile Chemistry.*
Ph.D., University of Vienna.
JOE ALTON MARLIN, *Associate Professor of Mathematics.*
Ph.D., North Carolina State University.
CULPEPPER PAUL MARSH, *Professor of Sociology and Anthropology.*
M.S., North Carolina State University.
DAVID BOYD MARSLAND, *Associate Professor of Chemical Engineering.*
Ph.D., Cornell University.
CLIFFORD K. MARTIN, *Assistant Professor of Soil Science.*
Ph.D., University of Illinois.
DAVID HAMILTON MARTIN, *Associate Professor of Physics.*
M.S., University of Wisconsin.
DONALD CHARLES MARTIN, *Assistant Professor of Statistics and Engineering Research.*
Ph.D., Florida University.
DONALD CROWELL MARTIN, *Associate Professor of Chemical Engineering.*
Ph.D., North Carolina State University.
LEROY BROWN MARTIN, JR., *Professor of Computer Science and Director of the Computing Center and Assistant to the Provost for University Computing.*
Ph.D., Harvard University.
ROBERT H. MARTIN, JR., *Assistant Professor of Mathematics.*
Ph.D., Georgia Institute of Technology.
BERNARD STEPHEN MARTOF, *Professor of Zoology.*
Ph.D., University of Michigan.
DAVID DICKENSON MASON, *Professor of Statistics and Head of the Department.*
Ph.D., North Carolina State University.
DON ALAN MASTERTON, *Associate Professor of Product Design.*
M.S., Illinois Institute of Technology.
GENE ARTHUR MATHIA, *Associate Professor of Economics.*
Ph.D., North Carolina State University.
GENNARD MATRONE, *William Neal Reynolds Professor of Biochemistry and Head of the Department.*
Ph.D., North Carolina State University.

NEELY FORSYTH JONES MATTHEWS, *Associate Professor of Electrical Engineering.*
Ph.D., Princeton University.

DALE FREDERICK MATZINGER, *Professor of Genetics.*
Ph.D., Iowa State College.

GEORGE MAYER, *Adjunct Associate Professor of Materials Engineering.*
Ph.D., Massachusetts Institute of Technology.

SELZ CABOT MAYO, *Professor of Sociology and Anthropology and Head of the Department.*
Ph.D., University of North Carolina.

WARREN LEE MCCABE, *R. J. Reynolds Professor of Chemical Engineering.*
PhD., University of Michigan.

GLENN CROCKER MCCANN, *Professor of Sociology and Anthropology and Graduate Administrator.*
Ph.D., Washington State College.

CHARLES BERNARD MCCANTS, *Professor of Soil Science and Head of the Department.*
Ph.D., Iowa State College.

JACKSON MEARNS MCCLAIN, *Associate Professor of Politics.*
Ph.D., University of Alabama.

WILLIAM FRED MCCLURE, *Associate Professor of Biological and Agricultural Engineering.*
Ph.D., North Carolina State University.

ROBERT EDMUND MCCOLLUM, *Associate Professor of Soil Science.*
Ph.D., University of Illinois.

RALPH JOSEPH MCCRACKEN, *Professor of Soil Science and Assistant Director of Research of the School of Agriculture and Life Sciences.*
Ph.D., Iowa State College.

KATHLEEN ANDERTON MCCUTCHEN, *Instructor in the School of Education.*
M.A., Columbia University.

PATRICK HILL MCDONALD, JR., *Harrelson Professor of Engineering Mechanics and Head of the Department.*
Ph.D., Northwestern University.

RALPH MCGREGOR, *Associate Professor of Textile Chemistry.*
Ph.D., Leeds University.

WILLIAM ALEXANDER MCINTOSH, *Adjunct Assistant Professor of Industrial and Technical Education.*
Ed.D., North Carolina State University.

WILLIAM THOMAS MCKEAN, JR., *Associate Professor of Wood and Paper Science.*
Ph.D., University of Washington.

JOHN JOSEPH MCNEILL, *Associate Professor of Animal Science and Microbiology.*
Ph.D., University of Maryland.

DONALD IRKERD MCREE, *Adjunct Assistant Professor of Engineering Mechanics.*
Ph.D., North Carolina State University.

FRANCIS EDWARD MCVAY, *Professor of Statistics.*
Ph.D., University of North Carolina.

JEFFERSON SULLIVAN MEARES, *Professor Emeritus of Physics.*
M.S., North Carolina State University.

GERHARD K. MEGLA, *Adjunct Professor of Electrical Engineering.*
Ph.D., University of Dresden, Dresden, Germany.

JASPER DURHAM MEMORY, *Professor of Physics and Assistant Dean, School of Physical and Mathematical Sciences.*
Ph.D., University of North Carolina.

ARTHUR CLAYTON MENIUS, JR., *Professor of Physics and Dean of the School of Physical and Mathematical Sciences.*
Ph.D., University of North Carolina.

CHARLES VENABLE MERCER, *Associate Professor of Sociology and Anthropology.*
Ph.D., University of North Carolina at Chapel Hill.

LAWRENCE EUGENE METTLER, *Professor of Genetics and Zoology.*
Ph.D., University of Texas.

LOUIS JOHN METZ, *Adjunct Professor of Forestry and Soil Science.*
Ph.D., Duke University.
CARL DEAN MEYER, *Assistant Professor of Mathematics.*
Ph.D., Colorado State University.
WALTER EARL MEYERS, *Associate Professor of English.*
Ph.D., University of Florida.
GORDON KENNEDY MIDDLETON, *Professor Emeritus of Crop Science.*
Ph.D., Cornell University.
MARION LAWRENCE MILES, *Associate Professor of Chemistry.*
Ph.D., University of Florida.
ROBERT DONALD MILHOLLAND, *Associate Professor of Plant Pathology.*
PhD., University of Minnesota.
CONRAD HENRY MILLER, *Professor of Horticultural Science.*
Ph.D., Michigan State University.
GROVER CLEVELAND MILLER, *Professor of Zoology.*
Ph.D., Louisiana State University.
HOWARD GEORGE MILLER, *Professor of Psychology and Head of the Department.*
Ph.D., Pennsylvania State University.
LATHAM LEE MILLER, *Associate Professor of Recreation Resources Administration.*
M.A., University of North Carolina at Chapel Hill.
PHILIP ARTHUR MILLER, *Professor of Crop Science and Genetics.*
Ph.D., Iowa State University.
TEXTON ROBERT MILLER, *Associate Professor of Agricultural Education and Graduate Administrator.*
Ph.D., Ohio State University.
WILLIAM DYKSTRA MILLER, *Professor Emeritus of Forestry.*
Ph.D., Yale University.
JEHANGIR FARHAD MIRZA, *Associate Professor of Civil Engineering.*
Ph.D., North Carolina State University.
WALTER JOSEPH MISTRIC, JR., *Professor of Entomology.*
Ph.D., Texas A&M University.
ADOLPHUS MITCHELL, *Professor Emeritus of Engineering Mechanics.*
M.S. C.E., University of North Carolina.
GARY EARL MITCHELL, *Associate Professor of Physics.*
Ph.D., Florida State University.
THEODORE BERTIS MITCHELL, *Professor Emeritus of Entomology.*
D.S., Harvard University.
KHOSROW LOUIS MOAZED, *Professor of Metallurgical Engineering.*
Ph.D., Carnegie Institute of Technology.
RICHARD DOUGLAS MOCHRIE, *Associate Professor of Animal Science.*
Ph.D., North Carolina State University.
MANSOUR H. M. MOHAMED, *Visiting Assistant Professor of Textile Technology.*
Ph.D., Manchester College of Science and Technology.
ROBERT HARRY MOLL, *Professor of Genetics and Horticultural Science.*
Ph.D., North Carolina State University.
THOMAS JOSEPH MONACO, *Assistant Professor of Horticultural Science.*
Ph.D., North Carolina State University.
DANIEL JAMES MONCOL, *Associate Professor of Animal Science.*
D.V.M., University of Georgia.
ROBERT JAMES MONROE, *Professor of Statistics.*
Ph.D., North Carolina State University.
LARRY KING MONTEITH, *Associate Professor of Electrical Engineering.*
Ph.D., Duke University.
CLIFFORD JAMES MOORE, JR., *Associate Professor of Mechanical and Aerospace Engineering.*
Ph.D., Southern Methodist University.
FRANK HARPER MOORE, *Professor of English.*
Ph.D., University of North Carolina.

HARRY BALLARD MOORE, JR., *Associate Professor of Entomology.*
Ph.D., North Carolina State University.
ROBERT PARKER MOORE, *Professor of Crop Science.*
Ph.D., Ohio State University.
ROYALL TYLER MOORE, *Associate Professor of Plant Pathology and Botany.*
Ph.D., Harvard University.
CHARLES GALLOWAY MOREHEAD, *Professor of Guidance and Personnel Services.*
Ed.D., University of Kansas.
CHARLES GLEN MORELAND, *Associate Professor of Chemistry.*
Ph.D., University of Florida.
DONALD EDWIN MORELAND, *Professor (USDA) of Crop Science and Botany.*
Ph.D., North Carolina State University.
ROBERT LEROY MORGAN, *Research Associate in the Center for Occupational Education.*
Ph.D., North Carolina State University.
MARVIN KENT MOSS, *Associate Professor of Physics.*
Ph.D., North Carolina State University.
TERUMI MUKAI, *Professor of Genetics.*
Ph.D., Purdue University.
WESLEY GRIGG MULLEN, *Professor of Civil Engineering.*
Ph.D., Purdue University.
JAMES COLVIN MULLIGAN, *Associate Professor of Mechanical and Aerospace Engineering.*
Ph.D., Tulane University.
CHARLES FRANKLIN MURPHY, *Associate Professor of Crop Science and Genetics.*
Ph.D., Iowa State University.
RAYMOND LEROY MURRAY, *Burlington Professor of Physics and Head of the Department of Nuclear Engineering.*
Ph.D., University of Tennessee.
ROBERT DAVID MUSTIAN, *Assistant Professor of Sociology and Anthropology.*
Ph.D., Florida State University.
RICHARD MONIER MYERS, *Associate Professor of Animal Science.*
M.S., Pennsylvania State University.
HOWARD MOVESS NAHIKIAN, *Professor of Mathematics and Graduate Administrator.*
Ph.D., University of North Carolina.
GENE NAMKOONG, *Professor (USFS) of Genetics and Forestry.*
Ph.D., North Carolina State University.
LAURENCE ALAN NELSON, *Professor of Statistics.*
Ph.D., North Carolina State University.
PAUL VICTOR NELSON, *Associate Professor of Horticultural Science.*
Ph.D., Cornell University.
JOSEPH TAFT NERDEN, *Professor of Industrial and Technical Education.*
Ph.D., Yale University.
HERBERT HENRY NEUNZIG, *Professor of Entomology.*
Ph.D., Cornell University.
SLATER EDMUND NEWMAN, *Professor of Psychology.*
Ph.D., Northwestern University.
THOMAS EVERETT NICHOLS, JR., *Extension Professor of Economics.*
Ph.D., Duke University.
PAUL ADRIAN NICKEL, *Professor of Mathematics.*
Ph.D., University of California at Los Angeles.
LOWELL WENDELL NIELSEN, *Professor of Plant Pathology.*
Ph.D., Cornell University.
STUART MCGUIRE NOBLIN, *Professor of History.*
Ph.D., University of North Carolina.
GLENN RAY NOGGLE, *Professor of Botany and Head of the Department.*
Ph.D., University of Illinois.
BRUCE AUGUSTUS NORTON, *Clinical Associate Professor of Psychology.*
Ph.D., Ohio State University.

CHARLES JOSEPH NUSBAUM, *William Neal Reynolds Professor of Plant Pathology.*
Ph.D., University of Wisconsin.
HENRY LEE WILLIAMSON NUTTLE, *Assistant Professor of Industrial Engineering.*
Ph.D., Johns Hopkins University.
BERNARD MARTIN OLSEN, *Professor of Economics.*
Ph.D., University of Chicago.
DELMAR WALTER OLSON, *Professor of Industrial and Technical Education and Coordinator of Graduate Studies in Industrial Arts.*
Ph.D., Ohio State University.
JOHN BENJAMIN O'NEAL, JR., *Associate Professor of Electrical Engineering.*
Ph.D., University of Florida.
RONALD WILLIAM OPPENHEIM, *Adjunct Assistant Professor of Psychology.*
Ph.D., Washington University.
GUY OWEN, JR., *Professor of English.*
Ph.D., University of North Carolina.
ROBERT GUY OWENS, *Adjunct Professor of Plant Pathology.*
Ph.D., Columbia University.
MEHMET NECATI OZISIK, *Professor of Mechanical and Aerospace Engineering.*
Ph.D., University of London.
LAVON BARRY PAGE, *Assistant Professor of Mathematics.*
Ph.D., University of Virginia.
HAYNE PALMOUR, III, *Research Professor of Ceramic Engineering.*
Ph.D., North Carolina State University.
CHIA-VEN PAO, *Assistant Professor of Mathematics.*
Ph.D., University of Pittsburgh.
HUBERT VERN PARK, *Professor of Mathematics and Assistant to the Department Head.*
Ph.D., University of North Carolina.
JAE YOUNG PARK, *Associate Professor of Physics.*
Ph.D., University of North Carolina.
CHARLES ALEXANDER PARKER, *Professor of English.*
Ph.D., Louisiana State University.
GEORGE WILLIAM PARKER, III, *Assistant Professor of Physics.*
Ph.D., University of South Carolina.
JOHN MASON PARKER, III, *Professor of Geosciences.*
Ph.D., Cornell University.
BARBARA MITCHELL PARRAMORE, *Assistant Professor in the Division of Education.*
Ed.D., Duke University.
GERALD E. PARSONS, *Assistant Professor of Adult and Community College Education.*
Ph.D., Iowa State University.
MARY PASCHAL, *Associate Professor of Modern Languages.*
Ph.D., University of North Carolina at Chapel Hill.
ERNEST CALEB PASOUR, JR., *Associate Professor of Economics.*
Ph.D., Michigan State University.
YALE NANCE PATT, *Associate Professor of Computer Science.*
Ph.D., Stanford University.
HAROLD EDWARD PATTEE, *Associate Professor (USDA) of Botany.*
Ph.D., Purdue University.
ROBERT PRESTON PATTERSON, *Assistant Professor of Crop Science.*
Ph.D., Cornell University.
RICHARD ROLAND PATTY, *Associate Professor of Physics.*
Ph.D., Ohio State University.
LALJI JAYANHLAL PAVAGADHI, *Assistant Professor of Mechanical and Aerospace Engineering.*
Ph.D., North Carolina State University.
RICHARD GUSTAVE PEARSON, *Professor of Psychology and Industrial Engineering.*
Ph.D., Carnegie Institute of Technology.
RONALD GRAY PEARSON, *Associate Professor of Wood and Paper Science.*
Ph.D., University of Melbourne.

RALPH JAMES PEELER, JR., *Associate Professor of Economics, Coordinator of Graduate Programs and Assistant Dean of the Graduate School.*
Ph.D., North Carolina State University.

JOHN NOBLE PERKINS, *Professor of Mechanical and Aerospace Engineering.*
Ph.D., Virginia Polytechnic Institute.

RONALD WILLIAM PERO, *Adjunct Assistant Professor of Plant Pathology.*
Ph.D., University of Rhode Island.

JEROME JOHN PERRY, *Professor of Microbiology.*
Ph.D., University of Texas.

THOMAS OLIVER PERRY, *Professor of Forestry and Genetics.*
Ph.D., Harvard University.

KEITH STUART PETERSEN, *Associate Professor of Politics.*
Ph.D., University of Chicago.

JAMES TEIGEN PETERSON, *Adjunct Assistant Professor of Meteorology.*
Ph.D., University of Wisconsin.

WALTER JOHN PETERSON, *William Neal Reynolds Professor of Chemistry and Dean of the Graduate School.*
Ph.D., University of Iowa.

WILBUR CARROLL PETERSON, *Associate Professor of Electrical Engineering.*
Ph.D., Northwestern University.

JOSEPH ALLEN PHILLIPS, *Extension Associate Professor of Soil Science.*
Ph.D., Iowa State University.

LYLE LLEWELLYN PHILLIPS, *Professor of Crop Science and Genetics.*
Ph.D., University of Washington.

JULIUS CARL POINDEXTER, JR., *Assistant Professor of Economics.*
Ph.D., University of North Carolina at Chapel Hill.

GEORGE WAVERLY POLAND, *Professor of Modern Languages and Head of the Department.*
Ph.D., University of North Carolina.

DANIEL TOWNSEND POPE, *Research Professor of Horticultural Science.*
Ph.D., Cornell University.

JOSEPH ALEXANDER PORTER, JR., *Professor of Textile Technology.*
M.S., North Carolina State University.

IRA DEWARD PORTERFIELD, *Professor of Animal Science and Head of the Department.*
Ph.D., University of Minnesota.

NATHANIEL THOMAS POWELL, *Professor of Plant Pathology and Genetics.*
Ph.D., North Carolina State University.

ANCO LUNING PRAK, *James T. Ryan Associate Professor of Industrial Engineering.*
Ph.D., North Carolina State University.

RICHARD JOSEPH PRESTON, *Professor Emeritus of Forestry and Dean Emeritus of the School of Forest Resources.*
Ph.D., University of Michigan.

CHARLES HARRY PROCTOR, *Professor of Statistics.*
Ph.D., Michigan State University.

CHARLES RAY PUGH, *Extension Professor of Economics.*
Ph.D., Purdue University.

ALBERT ERNEST PURCELL, *Professor (USDA) of Food Science.*
Ph.D., Purdue University.

THOMAS LAVELLE QUAY, *Professor of Zoology.*
Ph.D., North Carolina State University.

JOHN WILLIAM QUERRY, *Associate Professor of Mathematics.*
Ph.D., Iowa State University.

CHARLES PRICE QUESENBERRY, *Professor of Statistics.*
Ph.D., Virginia Polytechnic Institute.

EMILY HOTCHKISS QUINN, *Adjunct Professor of Adult and Community College Education.*
Ph.D., University of Wisconsin.

ROBERT LAMAR RABB, *Professor of Entomology.*
Ph.D., North Carolina State University.
ALLEN HUFF RAKES, *Associate Professor of Animal Science.*
Ph.D., Cornell University.
ROBERT TODD RAMSAY, *Assistant Professor of Mathematics.*
Ph.D., University of Miami.
HAROLD ARCH RAMSEY, *Professor of Animal Science.*
Ph.D., North Carolina State University.
CHARLES DAVID RAPER, JR., *Assistant Professor of Soil Science.*
Ph.D., Purdue University.
JOHN OREN RAWLINGS, *Professor of Statistics and Genetics.*
Ph.D., North Carolina State University.
HORACE DARR RAWLS, *Associate Professor of Sociology and Anthropology.*
Ph.D., Duke University.
RACHEL F. RAWLS, *Visiting Assistant Professor of Psychology.*
Ed.D., New York University.
ISAAC EPPS READY, *Visiting Professor of Adult and Community College Education.*
Ed.D., New York University.
WILLIS ALTON REID, *Professor of Chemistry.*
Ph.D., University of Wisconsin.
RICHARD ALLYN REINART, *Adjunct Associate Professor of Plant Pathology.*
Ph.D., University of Wisconsin.
GUNTHER JOHN PHILLIP REUER, *Associate Professor of Architecture.*
Ph.D., Frei University, Berlin.
MICHAEL SHANE REYNOLDS, *Assistant Professor of English.*
Ph.D., Duke University.
DONALD ROBERT RHODES, *University Professor of Electrical Engineering.*
Ph.D., Ohio State University.
THEODORE ROOSEVELT RICE, *Adjunct Professor of Zoology.*
Ph.D., Harvard University.
FRANCES MARIAN RICHARDSON, *Research Associate Professor of Engineering Research.*
M.S., University of Cincinnati.
JOHN MARION RIDDLE, *Associate Professor of History.*
Ph.D., University of North Carolina.
DON LEE RIDGEWAY, *Professor of Statistics and Physics.*
Ph.D., University of Rochester.
JACKSON ASHCRAFT RIGNEY, *Professor of Statistics and Dean for International Programs.*
M.S., Iowa State College.
THOMAS HUNTINGTON RIPLEY, *Adjunct Professor of Recreation Resources Administration.*
Ph.D., Virginia Polytechnic Institute.
JOHN FREDERICK ROBERTS, *Associate Professor of Zoology.*
Ph.D., University of Arizona.
WILLIAM MILNER ROBERTS, *Professor of Food Science and Head of the Department.*
Ph.D., University of Minnesota.
ROBERT LAFON ROBERTSON, *Extension Professor of Entomology.*
M.S., Auburn University.
ODIS WAYNE ROBISON, *Associate Professor of Animal Science and Genetics.*
Ph.D., University of Wisconsin.
THEODORE GEORGE ROCHOW, *Associate Professor of Textile Technology.*
Ph.D., Cornell University.
GEORGE CALVERT ROCK, *Associate Professor of Entomology.*
Ph.D., Cornell University.
CHARLES HERMAN ROGERS, *Research Associate Professor of Agricultural Education.*
Ed.D., Cornell University.
ROGER PHILLIP ROHRBACH, *Assistant Professor of Biological and Agricultural Engineering.*
Ph.D., Ohio State University.

ERNEST WILLIAM ROLLINS, *Assistant Professor of Modern Languages.*
Ph.D., Vanderbilt University.
NICHOLAS JOHN ROSE, *Professor of Mathematics and Head of the Department.*
Ph.D., New York University.
JOHN PAUL ROSS, *Professor (USDA) of Plant Pathology.*
Ph.D., Cornell University.
THELMA LOUISE ROUNDTREE, *Adjunct Professor of Education.*
Ph.D., Emory University.
RONALD W. ROUSSEAU, *Assistant Professor of Chemical Engineering.*
Ph.D., Louisiana State University.
LARRY HERBERT ROYSTER, *Associate Professor of Mechanical and Aerospace Engineering.*
Ph.D., North Carolina State University.
GEORGE DARRELL RUSSELL, *Assistant Professor of Adult Education.*
Ph.D.. University of Wisconsin.
LOUISE MAY RUSSELL, *Adjunct Professor of Entomology.*
M.S., Cornell University.
PAUL JAMES RUST, *Associate Professor of Education.*
Ph.D., University of Washington.
HENRY AMES RUTHERFORD, *Cone Mills Professor of Textile Chemistry and Head of the Department.*
M.S., George Washington University.
CURTIS W. SABROSKY, *Adjunct Professor of Entomology.*
M.S., Kansas State University.
HANS SAGAN, *Professor of Mathematics.*
Ph.D., University of Vienna.
REECE I. SAILER, *Adjunct Professor of Entomology.*
Ph.D., Kansas University.
PEDRO A. SANCHEZ, *Assistant Professor of Soil Science.*
Ph.D., Cornell University.
HENRY SANOFF, *Associate Professor of Architecture.*
M.Arch., Pratt Institute.
FRANK DORRANCE SARGENT, *Extension Associate Professor of Animal Science.*
Ph.D., North Carolina State University.
JOSEPH NEAL SASSER, *Professor of Plant Pathology.*
Ph.D., University of Maryland.
WALTER JOSEPH SAUCIER, *Professor of Meteorology.*
Ph.D., University of Chicago.
MAN MOHAN SAWHNEY, *Associate Professor of Sociology and Anthropology.*
Ph.D., Post-Graduate School, New Delhi.
RICHARD L. SAWYER, *Professor of Horticultural Science.*
Ph.D., Cornell University.
RAYMOND FREDERICK SAXE, *Professor of Nuclear Engineering.*
Ph.D., University of Liverpool, England.
LEROY CHARLES SAYLOR, *Professor of Genetics and Forestry and Assistant Dean of the School of Forest Resources.*
Ph.D., North Carolina State University.
CLARENCE CAYCE SCARBOROUGH, *Professor of Agricultural Education and Head of the Department.*
Ed.D., University of Illinois.
HENRY ELKIN SCHAFFER, *Associate Professor of Genetics.*
Ph.D., North Carolina State University.
JAN FREDERICK SCHETZINA, *Assistant Professor of Physics.*
Ph.D., Pennsylvania State University.
HAROLD EUGENE SCHLICHTING, JR., *Associate Professor of Botany.*
Ph.D., Michigan State University.
HOWARD A. SCHNEIDER, *Professor of Nutrition, Department of Animal Science.*
Ph.D., University of Wisconsin.

EDWARD MARTIN SCHOENBORN, JR., *Charles H. Herty Professor of Chemical Engineering.*
Ph..D., Ohio State University.

JOHN WILLIAM SCHRADER, *Assistant Professor of Crop Science.*
Ph.D., Michigan State University.

ANTON FRANZ SCHREINER, *Assistant Professor of Chemistry.*
Ph.D., University of Illinois.

RONALD ARTHUR SCHRIMPER, *Associate Professor of Economics.*
Ph.D., North Carolina State University.

HERBERT TEMPLE SCOFIELD, *Professor of Botany.*
Ph.D., Cornell University.

LEWIS WORTH SEAGONDOLLAR, *Professor of Physics and Head of the Department.*
Ph.D., University of Wisconsin.

JAMES ARTHUR SEAGRAVES, *Professor of Economics.*
Ph.D., Iowa State College.

JOHN FRANK SEELY, *Professor of Chemical Engineering.*
M.Ch.E., North Carolina State University.

HEINZ SELTMANN, *Associate Professor (USDA) of Botany.*
Ph.D., University of Chicago.

ERNEST DAVIS SENECA, *Assistant Professor of Botany and Soil Science.*
Ph.D., North Carolina State University.

HENRY ANTHONY SHANNON, *Associate Professor of Mathematics and Science Education.*
Ed.M., University of Missouri.

SAMUEL DAVID SHEARER, JR., *Adjunct Associate Professor of Civil Engineering.*
Ph.D., University of Wisconsin.

RONALD WILSON SHEARON, *Assistant Professor of Adult and Community College Education.*
Ed.D., North Carolina State University.

THOMAS JACKSON SHEETS, *Professor of Entomology, Crop Science and Horticultural Science.*
Ph.D., University of California at Davis.

VERNON FREDERICK SHOGREN, *Associate Professor of Architecture.*
M.Arch., Massachusetts Institute of Technology.

THOMAS CLINARD SHORE, JR., *Assistant Professor of Industrial and Technical Education.*
Ed.D., University of Maryland.

DONALD WOODS SHRIVER, JR., *Visiting Associate Professor of Religion.*
Ph.D., Harvard University.

RICHARD C. SHUMWAY, *Assistant Professor of Economics.*
Ph.D., University of California at Davis.

CHARLES EDWARD SIEWERT, *Associate Professor of Nuclear Engineering.*
Ph.D., University of Michigan.

ROBERT SILBER, *Assistant Professor of Mathematics.*
Ph.D., Clemson University.

RICHARD LEE SIMMONS, *Professor of Economics.*
Ph.D., University of California at Berkeley.

EDWARD CARROLL SISLER, *Associate Professor of Biochemistry and Crop Science.*
Ph.D., North Carolina State University.

RICHARD W. SKAGGS, *Assistant Professor of Biological and Agricultural Engineering and Soil Science.*
Ph.D., Purdue University.

WALTER ARTHUR SKROCH, *Extension Associate Professor of Horticultural Science.*
Ph.D., University of Wisconsin.

CHARLES SMALLWOOD, JR., *Professor of Civil Engineering.*
M.S., Harvard University.

FREDERICK OTTO SMETANA, *Professor of Mechanical and Aerospace Engineering.*
Ph.D., University of Southern California.

BENJAMIN WARFIELD SMITH, *Professor of Genetics.*
Ph.D., University of Wisconsin.
CLYDE FUHRIMAN SMITH, *Professor of Entomology.*
Ph.D., Ohio State University.
DONALD E. SMITH, *Associate Professor of Zoology.*
Ph.D, Ohio State University.
FARMER STERLING SMITH, *Assistant Professor of Industrial and Technical Education.*
Ed.D., North Carolina State University.
FRANK HOUSTON SMITH, *Professor of Animal Science.*
M.S., North Carolina State University.
GEORGE LOUIS SMITH, *Adjunct Assistant Professor of Mechanical and Aerospace Engineering.*
Ph.D., Virginia Polytechnic Institute.
HENRY BROWER SMITH, *Professor of Chemical Engineering and Associate Dean for Research and Graduate Studies, School of Engineering.*
Ph.D., University of Cincinnati.
J. C. SMITH, *Assistant Professor of Civil Engineering.*
Ph.D., Purdue University.
JAMES ROY SMITH, *Adjunct Associate Professor of Oceanography.*
M.S., Massachusetts Institute of Technology.
THOMAS EDWARD SMITH, *Assistant Professor of Engineering Mechanics.*
Ph.D., University of Illinois.
WILLIAM EDWARD SMITH, *Professor of Recreation Resources Administration.*
Ed.D., George Peabody College.
IAN NAISMITH SNEDDON, *Adjunct Professor of Mathematics.*
D.Sc., University of Glasgow, Scotland.
RUFUS HUMMER SNYDER, *Professor Emeritus of Physics.*
Ph.D., Ohio State University.
STANLEY MILTON SOLIDAY *Associate Professor of Industrial Engineering and Psychology.*
Ph.D., Ohio State University.
ARNOLD M. SOOKNÉ, *Adjunct Professor of Textile Chemistry.*
M.S., George Washington University.
KENNETH ALAN SORENSEN, *Extension Assistant Professor of Entomology.*
Ph.D., Kansas State University.
FURMAN YATES SORRELL, JR., *Associate Professor of Engineering Mechanics and Graduate Administrator.*
Ph.D., California Institute of Technology.
ROBERT SEAGO SOWELL, *Assistant Professor of Biological and Agricultural Engineering.*
Ph.D., North Carolina State University.
JASON LOY SOX, JR., *Assistant Professor of Mathematics.*
Ph.D., North Carolina State University.
JAMES MAURICE SPAIN, *Adjunct Professor of Soil Science.*
Ph.D., Purdue University.
MARVIN LUTHER SPECK, *William Neal Reynolds Professor of Food Science and Microbiology and Graduate Administrator in Food Science.*
Ph.D., Cornell University.
HERBERT ELVIN SPEECE, *Professor of Mathematics and Mathematics and Science Education and Head of the Department.*
Ph.D., University of North Carolina.
WILLIAM HENRY SPENCE, *Assistant Professor of Geosciences.*
Ph.D., Rutgers University.
JOHN D. SPRAGINS, *Adjunct Associate Professor of Electrical Engineering.*
Ph.D. Stanford University.
HARVEY WESLEY SPURR, JR., *Associate Professor (USDA) of Plant Pathology.*
Ph.D., University of Wisconsin.

EDWARD M. STACK, *Professor of Modern Languages.*
Ph.D., Princeton University.

HANS HEINRICH STADELMAIER, *Research Professor of Metallurgy in Engineering Research.*
Dr.rer.nat. Hochshule, Stuttgart, Germany.

EDWARD PAUL STAHEL, *Associate Professor of Chemical Engineering.*
Ph.D., Ohio State University.

EPHRAIM STAM, *Assistant Professor of Nuclear Engineering.*
Ph.D., Virginia Polytechnic Institute.

ALFRED J. STAMM, *Reuben B. Robertson Professor Emeritus of Wood and Paper Science.*
Ph.D., University of Wisconsin.

WILLIAM F. STANDAERT, *Assistant Professor of Zoology.*
Ph.d., Rutgers University.

VIVIAN THOMAS STANNETT, *Camille Dreyfus Professor of Chemical Engineering.*
Ph.D., Polytechnic Institute of Brooklyn.

JOHN STAUDHAMMER, *Professor of Electrical Engineering.*
Ph.D., University of California at Los Angeles.

ROBERT GEORGE DOUGLAS STEEL, *Professor of Statistics and Graduate Administrator.*
Ph.D., Iowa State University.

ALLEN FREDERICK STEIN, *Assistant Professor of English.*
Ph.D., Duke University.

STANLEY GEORGE STEPHENS, *William Neal Reynolds Professor of Genetics.*
Ph.D., Edinburgh University, Scotland.

ROBERT ELMER STERNLOFF, *Associate Professor of Recreation Resources Administration.*
Ph.D., University of Wisconsin.

ROBERT K. STEVENS, *Adjunct Associate Professor of Wood and Paper Science.*
M.S., Virginia Polytechnic Institute.

WILLIAM DAMON STEVENSON, JR., *Professor of Electrical Engineering, Associate Head of the Department and Graduate Administrator.*
M.S., University of Michigan.

HAMILTON ARLO STEWART, *Professor Emeritus of Animal Science.*
Ph.D., University of Minnesota.

ERNEST LESTER STITZINGER, *Assistant Professor of Mathematics.*
Ph.D., University of Pittsburgh.

ROBERT FRANKLIN STOOPS, *Research Professor of Ceramic Engineering and Acting Head of Engineering Research.*
Ph.D., Ohio State University.

DAVID LEWIS STRIDER, *Professor of Plant Pathology.*
Ph.D., North Carolina State University.

RAYMOND WILLIAM STROH, *Assistant Professor of Electrical Engineering.*
Ph.D., Polytechnic Institute of Brooklyn.

RAIMOND ALDRICH STRUBLE, *Professor of Mathematics.*
Ph.D., University of Notre Dame.

DUNCAN ROBERT STUART, *Professor of Design.*

CHARLES WILLIAM STUBER, *Associate Professor (USDA) of Genetics.*
Ph.D., North Carolina State University.

WILLIAM CLIFTON STUCKEY, JR., *Associate Professor of Textile Technology.*
M.S., North Carolina State University.

STANLEY KENDRICK SUDDARTH, *Adjunct Professor of Wood and Paper Science.*
Ph.D., Purdue University.

CHARLES WILSON SUGGS, *Professor of Biological and Agricultural Engineering.*
Ph.D., North Carolina State University.

JAMES EDWARD SUNDERLAND, *R. J. Reynolds Tobacco Co. Professor of Mechanical and Aerospace Engineering.*
Ph.D., Purdue University.

JOSEPH GWYN SUTHERLAND, *Research Professor (USDA) of Economics.*
Ph.D., North Carolina State University.
PAUL PORTER SUTTON, *Professor of Chemistry.*
Ph.D., Johns Hopkins University.
ELIZABETH MANNY SUVAL, *Assistant Professor of Sociology and Anthropology.*
Ph.D., North Carolina State University.
STANLEY S. SUVAL, *Associate Professor of History.*
Ph.D., University of North Carolina at Chapel Hill.
HAROLD EVERETT SWAISGOOD, *Associate Professor of Food Science.*
Ph.D., Michigan State University.
ERNST WARNER SWANSON, *Professor Emeritus of Economics.*
Ph.D., University of Chicago.
BENEE FRANK SWINDEL, *Associate Professor (USFS) of Forestry and Statistics.*
Ph.D., North Carolina State University.
RICHARD EUGENE SYLLA, *Associate Professor of Economics.*
Ph.D., Harvard University.
BANKS C. TALLEY, JR., *Dean of Student Affairs.*
Ph.D., University of North Carolina at Chapel Hill.
CHARLES CARSON TAPPERT, *Adjunct Assistant Professor of Electrical Engineering.*
Ph.D., Cornell University.
FRED RUSSELL TARVER, JR., *Extension Associate Professor of Food Science.*
Ph.D., University of Georgia.
DAVID LEE TERRY, *Extension Assistant Professor of Soil Science.*
Ph.D., North Carolina State University.
CECIL FRED TESTER, *Assistant Professor (USDA) of Crop Science and Genetics.*
Ph.D., University of Georgia.
ALAN LEE THARP, *Assistant Professor of Computer Science.*
Ph.D., Northwestern University.
ELIZABETH C. THEIL, *Assistant Professor of Biochemistry.*
Ph.D., Columbia University.
MICHAEL HERBERT THEIL, *Assistant Professor of Textile Chemistry.*
Ph.D., Polytechnic Institute of Brooklyn.
LLEWELLYN HILLETH THOMAS, *Visiting University Professor of Physics.*
D. Sc., Cambridge University.
RICHARD JOSEPH THOMAS, *Professor of Wood and Paper Science and Botany.*
Ph.D., Duke University.
DONALD LORAINE THOMPSON, *Research Professor (USDA) of Crop Science and Genetics.*
Ph.D., Iowa State College.
EDWIN GILBERT THURLOW, *Professor of Landscape Architecture.*
M.L.A., Harvard University.
DAVID RONALD TILLEY, *Associate Professor of Physics.*
Ph.D., Johns Hopkins University.
ROBERT O. TILMAN, *Professor of Politics and Dean of the School of Liberal Arts.*
Ph.D., Duke University.
DAVID HARRY TIMOTHY, *Professor of Crop Science, Botany and Genetics.*
Ph.D., University of Minnesota.
FREDERICK JOSEPH TISCHER, *Professor of Electrical Engineering.*
Ph.D., University of Prague, Czechoslovakia.
WILLIAM BELL TOOLE, III, *Professor of English.*
Ph.D., Vanderbilt University.
WILLIAM DOUGLAS TOUSSAINT, *Professor of Economics and Head of the Department.*
Ph.D., Iowa State College.
SAMUEL B. TOVE, *Professor of Animal Science and Biochemistry.*
Ph.D., University of Wisconsin.
CURTIS TRENT, *Professor of Adult and Community College Education.*
Ph.D., University of Wisconsin.

ANASTASIOS CHRISTOS TRIANTAPHYLLOU, *Professor of Genetics.*
Ph.D., North Carolina State University.
HEDWIG HIRSCHMANN TRIANTAPHYLLOU, *Professor of Plant Pathology.*
Ph.D., University of Erlangen, Germany.
JAMES RICHARD TROYER, *Professor of Botany.*
Ph.D., Columbia University.
ROBERT WESLEY TRUITT, *L. L. Vaughan Professor of Mechanical and Aerospace Engineering and Head of the Department.*
Ph.D., Virginia Polytechnic Institute.
HARRY TUCKER JR., *Associate Professor of Modern Languages.*
Ph.D., Ohio State University.
WILLIAM PRESTON TUCKER, *Associate Professor of Chemistry and Biochemistry and Director of Graduate Studies in Chemistry.*
Ph.D., University of North Carolina.
JERRY J. TULIS, *Adjunct Associate Professor of Microbiology.*
Ph.D., Catholic University.
CHI CHOA TUNG, *Associate Professor of Civil Engineering.*
Ph.D., University of California at Berkeley.
CARL BYRON TURNER, *Associate Professor of Economics.*
Ph.D., Duke University.
LESTER CURTISS ULBERG, *Professor of Animal Science.*
Ph.D., University of Wisconsin.
DAVID FREDERICK ULLRICH, *Assistant Professor of Mathematics.*
Ph.D., Carnegie Institute of Technology.
CLAUDE RICHARD UNRATH, *Assistant Professor of Horticultural Science.*
Ph.D., Michigan State University.
MARGARET N. UTLEY, *Clinical Assistant Professor of Psychology.*
Ph.D., Duke University.
MEHMET ENSAR UYANIK, *Professor of Civil Engineering.*
Ph.D., University of Illinois.
ODELL UZZELL, *Associate Professor of Sociology and Anthropology.*
Ph.D., Ohio State University.
JOHN G. VANDENBERGH, *Adjunct Associate Professor of Zoology.*
Ph.D., Pennsylvania State University.
HUBERTUS ROBERT VAN DER VAART, *Professor of Statistics and Mathematics.*
Ph.D., Leiden University, Netherlands.
CECIL GERALD VAN DYKE, *Assistant Professor of Botany and Plant Pathology.*
Ph.D., University of Illinois.
KURUVILLA VERGHESE, *Associate Professor of Nuclear Engineering.*
Ph.D., Iowa State University.
RICHARD JAMES VOLK, *Professor of Soil Science and Horticultural Science.*
Ph.D., North Carolina State University.
GEORGE HENRY WAHL, JR., *Associate Professor of Chemistry.*
Ph.D., New York University.
HARVEY EDWARD WAHLS, *Professor of Civil Engineering and Graduate Administrator.*
Ph.D., Northwestern University.
JAY TOWNSEND WAKELEY, *Adjunct Professor of Statistics.*
Ph.D., North Carolina State University.
JAMES LESTER WALKER, *Visiting Associate Professor (AID) of Soil Science.*
Ph.D., University of Hawaii.
MONROE ELIOT WALL, *Adjunct Professor of Chemistry.*
Ph.D., Rutgers University.
JAMES CLARENCE WALLACE, *Associate Professor of University Studies.*
M.A., University of North Carolina at Chapel Hill.
THOMAS DUDLEY WALLACE, *Professor of Economics and Statistics.*
Ph.D., University of Chicago.
RICHARD GAITHER WALSER, *Professor Emeritus of English.*
M.A., University of North Carolina.

WILLIAM KERSHAW WALSH, *Assistant Professor of Textile Chemistry.*
Ph.D., North Carolina State University.
WILLIAM MOOD WALTER, JR., *Associate Professor (USDA) of Food Science.*
Ph.D., University of Georgia.
THOMAS NOBLE WALTERS, *Assistant Professor of English and Education.*
Ed.D., Duke University.
ARTHUR WALTER WALTNER, *Professor of Physics.*
Ph.D., University of North Carolina.
THOMAS MARSH WARD, *Assistant Professor of Chemistry.*
Ph.D., North Carolina State University.
FREDERICK GAIL WARREN, *Professor of Food Science.*
Ph.D., Pennsylvania State College.
MARLIN ROGER WARREN, JR., *Assistant Professor of Recreation Resources Administration.*
Dr.Rec., University of Indiana.
JOHN LOUIS WASIK, *Associate Professor of Statistics and Psychology.*
Ed.D., Florida State University.
WILLIAM MEADE WATERS, JR., *Assistant Professor of Mathematics and Science Education and Mathematics.*
Ph.D., Florida State University.
DONOVAN LLOYD WAUGH, *Visiting Associate Professor (AID) of Soil Science.*
Ph.D., University of Wisconsin.
NEIL BROYLES WEBB, *Associate Professor of Food Science.*
Ph.D., University of Missouri.
ALLEN HOWARD WEBER, *Assistant Professor of Meteorology.*
Ph.D., University of Utah.
JEROME BERNARD WEBER, *Professor of Crop Science and Soil Science.*
Ph.D., University of Minnesota.
STERLING BARG WEED, *Professor of Soil Science.*
Ph.D., North Carolina State University.
GERALD THOMAS WEEKMAN, *Extension Professor of Entomology.*
Ph.D., Iowa State University.
CHARLES WILLIAM WELBY, *Associate Professor of Geosciences.*
Ph.D., Massachusetts Institute of Technology.
FREDERICK LOVEJOY WELLMAN, *Professor Emeritus of Plant Pathology.*
Ph.D., University of Wisconsin.
BERTRAM WHITTIER WELLS, *Professor Emeritus of Botany.*
Ph.D., University of Chicago.
CAROL GLENN WELLS, *Adjunct Associate Professor of Soil Science and Forestry.*
Ph.D., University of Wisconsin.
J. C. WELLS, *Extension Professor of Plant Pathology.*
M.S.A., University of Georgia.
ROBERT CHARLES WELLS, *Extension Associate Professor of Economics.*
Ph.D., Cornell University.
RONALD EARLE WELTY, *Associate Professor (USDA) of Plant Pathology.*
Ph.D., University of Minnesota.
EARL ALLEN WERNSMAN, *Associate Professor of Crop Science and Genetics.*
Ph.D., Purdue University.
DENNIS WILLIAM WERTZ, *Assistant Professor of Chemistry.*
Ph.D., University of South Carolina.
OSCAR WESLER, *Professor of Statistics and Mathematics.*
Ph.D., Stanford University.
BERT WHITLEY WESTBROOK, *Associate Professor of Psychology.*
Ed.D., Florida State University.
JOSEPH ARTHUR WEYBREW, *William Neal Reynolds Professor of Crop Science.*
Ph.D., University of Wisconsin.
MARY ELIZABETH WHEELER, *Assistant Professor of History.*
Ph.D., University of North Carolina at Chapel Hill.

THOMAS BURTON WHITAKER, *Associate Professor (USDA) of Biological and Agricultural Engineering.*
Ph.D., Ohio State University.

RAYMOND CYRUS WHITE, *Professor of Chemistry.*
Ph.D., West Virginia University.

ROBERT BENJAMIN WHITE, JR., *Associate Professor of English.*
Ph.D., University of North Carolina at Chapel Hill.

JOHN KERR WHITFIELD, *Associate Professor of Mechanical and Aerospace Engineering.*
Ph.D., Virginia Polytechnic Institute.

LARRY ALSTON WHITFORD, *Professor Emeritus of Botany.*
Ph.D., Ohio State University.

JOHN CLARK WILK, *Associate Professor of Animal Science.*
Ph.D., University of Minnesota.

RICHARD R. WILKINSON, *Professor of Landscape Architecture and Forest Resources and Head of the Department of Landscape Architecture.*
M.L.A., University of Michigan.

CLIFF RUFUS WILLEY, *Associate Professor (USDA) of Agricultural Engineering.*
Ph.D., University of Wisconsin.

JAMES CLIFFORD WILLIAMS, III, *Professor of Mechanical and Aerospace Engineering.*
Ph.D., University of Southern California.

JAMES OLIVER WILLIAMS, *Assistant Professor of Politics.*
Ph.D., University of North Carolina at Chapel Hill.

MARY BEARDEN WILLIAMS, *Assistant Professor of Statistics.*
Ph.D., University of London.

PORTER WILLIAMS, JR., *Associate Professor of English.*
M.A., Cambridge University; University of Virginia.

RICHARD BIRGE WILLIAMS, *Adjunct Associate Professor of Zoology.*
Ph.D., Harvard University.

JAMES CLAUDE WILLIAMSON, JR., *Professor of Economics and Director of Research, School of Agriculture and Life Sciences.*
M.S., North Carolina State University.

RALPH EDWARD WILLIAMSON, *Associate Professor (USDA) of Biological and Agricultural Engineering and Botany.*
Ph.D., University of Wisconsin.

JAMES BLAKE WILSON, *Associate Professor of Mathematics.*
Ph.D., University of Florida.

NASH NICKS WINSTEAD, *Professor of Plant Pathology and Assistant Provost.*
Ph.D., University of Wisconsin.

LOWELL SHERIDAN WINTON, *Professor of Mathematics.*
Ph.D., Duke University.

GEORGE HERMAN WISE, *William Neal Reynolds Professor of Animal Science.*
Ph.D., University of Minnesota.

EDWARD HEMPSTEAD WISER, *Associate Professor of Biological and Agricultural Engineering.*
Ph.D., North Carolina State University.

PETER NICOLAS WITT, *Adjunct Professor of Zoology.*
M.D., University of Tuebingen.

DOUGLAS ARTHUR WOLFE, *Adjunct Associate Professor of Zoology.*
Ph.D., Ohio State University.

WILLIAM GARLAND WOLTZ, *Professor of Soil Science.*
Ph.D., Cornell University.

JAMES WOODBURN, *Professor of Mechanical and Aerospace Engineering.*
Dr. Engr., Johns Hopkins University.

WILLIAM WALTON WOODHOUSE, JR., *Professor of Soil Science.*
Ph.D., Cornell University.

ROBERT WYLLIE WORK, *Professor of Textiles and Director of Textile Research.*
Ph.D., Cornell University.

ARCH DOUGLAS WORSHAM, *Professor of Crop Science.*
Ph.D., North Carolina State University.

JIMMIE JACK WORTMAN, *Adjunct Associate Professor of Electrical Engineering.*
Ph.D., Duke University.

CHARLES GERALD WRIGHT, *Associate Professor of Entomology.*
Ph.D., North Carolina State University.

ROBERT TAKICHI YAMAMOTO, *Associate Professor of Entomology.*
Ph.D., University of Illinois.

EDWARD CARSON YATES, JR., *Adjunct Associate Professor of Mechanical and Aerospace Engineering.*
Ph.D., Virginia Polytechnic Institute.

DAVID ALLEN YOUNG, JR., *Professor of Entomology.*
Ph.D., University of Kansas.

JAMES HERBERT YOUNG, *Associate Professor of Biological and Agricultural Engineering.*
Ph.D., Oklahoma State University.

JAMES NEAL YOUNG, *Professor of Sociology and Anthropology.*
Ph.D., University of Kentucky.

TALMAGE BRIAN YOUNG, *Associate Professor of Industrial Arts Education.*
Ed.D., University of Florida.

MOHAMED GAMAL ZAALOUK, *Visiting Assistant Professor of Electrical Engineering.*
Ph.D., North Carolina State University.

DONALD C. ZEIGER, *Associate Professor of Horticultural Science.*
Ph.D., Rutgers University.

PAUL ZUNG-TEH ZIA, *Professor of Civil Engineering and Associate Head of the Department.*
Ph.D., University of Florida.

BRUCE J. ZOBEL, *Edwin F. Conger Professor of Forestry and Genetics.*
Ph.D., University of California.

CARL FRANK ZOROWSKI, *R. J. Reynolds Tobacco Co. Professor of Mechanical Engineering and Associate Head of the Department of Mechanical and Aerospace Engineering.*
Ph.D., Carnegie Institute of Technology.

LLOYD ROBERT ZUMWALT, *Professor of Nuclear Engineering.*
Ph.D., California Institute of Technology.

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